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LECTURE.

Friday, January 17th, 1873.

Admiral Sir ALEXANDER MILNE, G.C.B., Lord of the Admiralty, in the Chair.

POWDER PRESSURES IN THE FIRST 35-TON GUN.

By Commander W. Dawson, R.N.

"*With hard projectiles having * * * * studs, there will generally be a slightly oblique movement of the axis of the projectile.*"—Modern Artillery.

"*The gun rifled on the French*" (Woolwich) "*system has decidedly the lowest velocities.*"—Ordnance Select Committee, 1864.

"*It is the maximum pressure which causes the failure of the stud.*"—Sir W. G. Armstrong, 1870.

The Chairman: Gentlemen, having been requested by the Council to take the chair at this, the first meeting of the year, it affords me great pleasure to do so, because I have always felt that this Institution has been of great value to both our Services. I think it is only right for me to say, that the lecturers who have appeared before us here on previous occasions, have not only benefited the Institution, but have conferred a general benefit on the Services at large. I do not attend here to-day in my official capacity, but I come here as your Chairman, to act independently in that capacity, and so doing, I have very great pleasure in introducing to your notice Commander Dawson, who will now proceed to deliver his lecture.

Commander Dawson: The Surveyor-General of the Ordnance observed, 2nd March, 1872, "that he should be glad if the Com-"mittee turned their attention to the remarkable results of firing "large charges of pebble-powder. He has never been satisfied "with the discrepancies as to the amount of pressure produced "by a comparatively small increase in the charge of powder."* The Committee on Explosives report, 1st April, 1872, that "*When*

* See "Extracts from the Proceedings of the Department of the Director of Artillery," vol. x, Part II, page 86.

"*a charge of any description of powder* is increased beyond a certain limit, wave or local pressures are set up which strain the "gun unduly, *without affording an equivalent of useful effect on the* "*projectile.*" And the Special Committee report, 12th February, 1872, "that heavy guns, proved under the existing regulations, "are subjected to very undue local pressures, resulting in local en-"largements, dents, and even occasionally in cracked tubes."† * * "The Committee are perfectly aware of the great strength of our "heavy guns, and of the fact that they do stand the existing proof "without danger of bursting, but they cannot consider the local "enlargements of the bore, the dents, &c., which frequently occur on "proof, as at all desirable."‡ The "proof" charges here referred to, except in the case of the 35-ton gun, are $1\frac{1}{4}$ times those diminished weights of gunpowder, which are mis-called "battering charges," and are fired horizontally with the ordinary service projectiles. After "proof," and during cool training-practice with reduced charges, similar liabilities obtain, so that Inspectors of Ordnance are appointed to register the damages inflicted upon the bore during the exit of every fifty projectiles. These Inspectors are told in the *Official Text Book of the construction and manufacture of the rifled ordnance in the British Service*, corrected up to January, 1872, p. 175, that "there are certain "defects to which all guns are liable, such as 'tool marks,' or "irregularities in the boring and rifling during manufacture; 'dents' "or 'abrasions,' caused by the bursting of a shell in the bore; and "wearing at the sides of the 'grooves' from the friction of the studs of "projectiles." "Woolwich" rifled guns are also liable to erosion from the escaping gases, or hard, deep, roughness in the lands and grooves over, and in front of, the seat of the projectiles. The studs and the walls of the projectiles are also liable to certain marks and injuries of so serious a nature, that every recovered service projectile has to be destroyed§, and the "proof" ones restudded.

It seems not impossible that some connection may obtain between the Surveyor General's question about "the discrepancies as to the "amount of pressure produced by a comparatively small increase in "the charge of powder," and the "dents," "abrasions," "local "enlargements," and roughnesses of the bore, alluded to by the Special Committee; as well as with the shearing or wedging of the studs and the base-marks and compression of the walls of the projectile referred to elsewhere by the talented Superintendents of the Royal Gun Factories and of the Royal Laboratory, and in the official work on *Ammunition*, part II, pages 58, 73, &c. This idea seems not unreasonable, as the learned Professor of Artillery points out that "with hard pro-"jectiles having * * * * studs, there will generally be a slightly "oblique movement of the axis of the projectile." The force of this wriggling action would naturally increase with the greater violence of

† See "Extracts from the Proceedings of the Department of the Director of Artillery," vol. x, Part II, page 81. ‡ Ibid., page 85.

§ The recovered projectiles, whether chilled or not, are sent to the Royal Laboratory, where the brass studs are drilled out—a costly operation—and the old iron is then returned to the furnace.

large powder charges, and with the obstructions experienced by the studs of the escaping projectile. This view is further confirmed by comparing the Report of the late Ordnance Select Committee upon a large number of similar 7-inch projectiles fired under identical conditions except as to the agency for producing rotation, that the gun rifled "on the French (Woolwich) system, has decidedly the lowest velocities"* with the damaged condition of 70 per cent. of the recovered studded shell and the position of the injuries to the lands and grooves of the gun which had thus absorbed within its bore the force represented by the difference between the speed of the fastest competitive shot and of the studded one which had "decidedly the lowest velocities." (See Plate III.)

The History of the late 35-ton Gun.—The powder pressures registered in the late 35-ton gun afford the best known means of investigating Sir Henry Stork's problem. Of no other heavy gun, has the history of its conception, manufacture, trial, and failure been so carefully registered and published. Though the official examinations do not appear to have extended to the recovered projectiles, and those of the bore do not appear to have been made with scientific exactitude, until the gun gave way, yet the published register of each of the 73 rounds fired, with the corresponding pressures, is full of fruitful lessons.

The Intended Charge.—From "the Report of the Ordnance Council "on the proposed 35-ton gun competition," 4th May, 1870, we learn that Colonel F. A. Campbell, R.A., the talented Superintendent, Royal Gun Factories, designed the 11·6-inch bore for *a charge of 120 lbs. and a 700-lbs. projectile.* Sir W. G. Armstrong and Co. also proposed "*a charge of 120 lbs. of powder*, and a projectile weighing 700 "lbs. for this (12-inch) gun;" adding, "but we are willing *that any* "*charge* and weight of projectile which may be used with a competing "gun of equal weight, should be used also with our gun." Sir William Armstrong further "points out that in future, where much milder "powder will be used, the strain upon the studs will be proportionally "less, because, *of course, it is the maximum pressure which causes the* "*failure of the stud*, and as you reduce the maximum pressure, so you "increase the stability of the stud." Sir Joseph Whitworth substantially agreed with these two great artillery authorities as to the power of useful powder-consumption to be expected from the 35-ton gun, inasmuch as he fixed the powder charge, for such a 12-inch gun with polygonal rifling, at 117 lbs. with 750-lbs. projectiles, his proposed armour shells being $3\frac{1}{2}$ and 5 diameters long, of 880 and 1,250 lbs. weight, and containing 36 lbs. and 58 lbs. bursting charges respectively, instead of the $8\frac{7}{8}$-lbs. bursters now used.

The Present "Proof" Charge.—The powder charge now adopted has been reduced from 120 lbs. to 110 lbs. and 85 lbs. of the "milder powder," with projectiles of 700 and 616 lbs. in weight. Moreover, even these reduced charges are intended to be very sparingly used, for the second 12-inch 35-ton gun had been, at the end of the year, eight months at Shoeburyness for range finding, and had only fired

* See "Extracts from Reports, &c., Ordnance Select Committee," vol. ii, p. 292, sec. 13.

nineteen 110-lbs. reduced charges at low elevations and at considerable intervals of time, besides 46 small 85 lbs. P. charges. It appears also that, even for the "proof" of 35-ton guns, two rounds of service shot with reduced charges are alone used; though the usual proof in other heavy guns is two rounds with service shot, and $1\frac{1}{4}$ times the amount of powder in the highest service charge. But we are officially told that this latter test results, in other guns, "in local enlargements, dents, and "even occasionally in cracked tubes." And, the official "*Extracts of* "*Artillery Proceedings*" tell us, 4 : 3 : 72, that the Superintendent, Royal Gun Factories, "proposes that the proof charge for the 12-inch "gun of 35-tons shall be 115 lbs. To this the Committee have no "'objection, believing that two rounds of such a" reduced "charge "will not be a dangerous proof. He also concurs with the Committee "in thinking it advisable that the proof of heavy guns should com- "mence with a service charge. Therefore, the proof of the present "pattern 12-inch gun of 35-tons would be:—

"1 round, 110 lbs. pebble powder"
"1 round, 115 lbs. pebble powder"* } The gun having been designed to fire ordinarily, with elevation, and quick firing against a foe, 120 lbs. of powder.

"Projectiles of service weight being used in each case."

It will be observed that this "proof" with two reduced charges does not include firing with elevation, with heated chamber, with violent quick-burning powder, such as it may be necessary to employ on service, or with projectiles longer than 2·61 calibres capable of containing only $8\frac{7}{8}$ lbs. bursters. In other words, not only does the maximum test come short of what the gun was originally designed to endure in ordinary service, but it also comes short of what the gun would still have to endure in an ordinary naval bombardment, using the reduced charge of 110 lbs. at high elevations, in continuous and rapid firing.

Lack of Endurance.—The ostensible cause of this reduction of powder-charge, and weight of common shell, is the irregular and excessive pressures registered in the chamber of the first 35-ton gun. But the real cause is the very limited and sickly life endured by the grooved portion of the bore of that gun. Whether this limited endurance of the grooves and lands be the cause or the effect of the erratic pressures within the powder chamber, is questioned. A brief life might, however, have been predicated for this gun, not only from a consideration of the inverse ratio of endurance to weight in other "Woolwich" ordnance, but also of the evidence given by the Superintendent of the Royal Gun Factories before the Ordnance Council, which assembled at the War Office on the 4th May, 1870. This Officer stated very clearly his misgivings as to the system of rifling to be adopted, and the difficulty of thus rotating efficiently a sufficiently long projectile without such an increase of grooves as would be most prejudicial to the gun. He said:—"The stud in the projectile confines us to giving a less twist "than I should like to give to any gun. * * * * In heavy guns the "liability to shear, necessitates an increased number of grooves if a

* Possibly *two* rounds of 115 lbs. P. and one 110 lbs. P. are intended.

"quicker twist than now employed is given. *The system has the great* "*disadvantage of local scoring.*"

Milder Powder and Studs.—True, Sir William Armstrong unprophetically expressed "the greatest possible confidence that, with an "accelerating twist and the milder form of powder that will hereafter "be used, there is nothing to apprehend whatever from the stud "shearing. * * I think they have stood perfectly well, and in "standing perfectly well as they have done, we have a guarantee that "they will stand better in future, because the strain upon them will "be so very much lighter, not only from the milder powder, but from "the mode of rifling;"* quite ignoring the fact, that the same sized stud is used to support and rotate a 700 lbs. shot as one of 115 lbs. weight.

Colonel Campbell does not appear to have shared either Sir William Armstrong's confidence as to the "milder powder," nor as to the endurance of the studs, stating that "the stud on the projectile confines "us to giving a less twist than I should like to give to any gun. * * "We are afraid on account of the shearing of the stud. * * * I "have seen them shear as much as" one-tenth of an inch, "and for that "reason I should be afraid to give a greater twist than I have."† Being cross examined as to his experience of studs, Colonel Campbell maintained his convictions as to the evil influence of short-bearing studs on rotation, and hence upon endurance.

The 11·6 *inch* 35-*ton Gun.*—The 11·6 inch 35-ton gun was built and rifled with an accelerated twist on the French stud, or so-called "Woolwich" system.

During the first four months of 1871, thirty-five 11·6 inch 700-lbs. shot were projected horizontally with charges of 75, 100, 110, 115 and 120 lbs. of W.A.P. and Belgian P. powder—one discharge, the 8th, being with 130 lbs., or ten pounds more than that originally intended. No great mischief to the gun appears to have resulted from this four months' work. The condition of the shot is not stated.

The 12-*inch Bore.*—The barrel was then bored up to 12 inches. By taking a shaving of two-tenths of an inch off the inside, the roughnesses and abrasions in the interior were erased, and the bore came out of the factory with a polished surface like a new gun. For all practical purposes the 12-inch bore may be safely regarded as making the 35-ton gun a new weapon.

During the three-and-a-half months, ending with the last day of January, 1872, thirty-eight 12-inch 700-lbs. projectiles were fired horizontally from this new bore, with 110, 115 and 120 lbs. W.A.P. and Belgian P. charges.

"At a weekly meeting held at the War Office, 6th February, 1872, "it was decided to recommend that no further trial of this gun should "be made at present." And some weeks later, the gun was removed into the factory, where its B. tube or chase was cut off, its interior steel barrel and its cascable bored out, and a new interior steel barrel, a new

* See Parliamentary paper, No. 308 of 1870, "Report of the Ordnance Council on the Proposed 35-ton Gun Competition," page 13.

† Ibid., pages 11, 12.

cascable, and a new B. tube or chase substituted. Thus rebuilt, the gun will probably be as capable as before of enduring 38 horizontal discharges, spread over three and a half months.

The Practice Table.—The Report of the Committee on Explosive Substances, dated 1st April, 1872, has appended to it two very valuable though incomplete documents. One of these is a Practice Table, giving the detail of each of the 73 rounds fired from the 35-ton M.L.R. gun, showing the brand and weight of powder and the point of ignition in the cartridge, with the corresponding observed velocities at 110 and at 132 feet; and the maximum pressures registered by crusher-guages at (A) the inner end of the bore in line with the axis, at (B) the vent, 12 inches outwards, and at (C) the base of the shot, which should sustain the greatest pressure when it has advanced about six inches from its seat, or (with 120-lbs. charge) about $33\frac{1}{2}$ inches from the inner end of the bore. I have divided this table into two parts for the 11·6-inch and for the 12-inch bores respectively, and I have added a column showing the correspondence, or, rather, lack of correspondence, between the expulsive pressure exerted upon the base of the projectile, and the striking force resulting therefrom at 110 feet from the gun.

The State of the Bore.—The other valuable document appended to the Committee's Report is the result of special examinations of the state of the interior before firing at all, and after the 6th, 8th, 20th, and 29th round with the 11·6-inch bore. These examinations do not appear to have been made with scientific exactitude, yet the pressures agree very fairly with the reported state of the bore. But no examination took place before boring out all the hard, deep roughnesses made by the gases in the lands and grooves, the local enlargement of the barrel, and the burrs on the edges of the grooves, *i.e.*, in the process of conversion into a 12-inch gun. Official examinations were made of the 12-inch barrel before firing, and of the damages inflicted upon it, whilst discharging 12, 33, and 38 projectiles.

I have summarised the Reports of these examinations in a column appended to each Practice Table, so as to place the pressures and the state of the bore in juxtaposition, and I have prepared Plate I to illustrate the longitudinal position of the principal injuries found in the interior of the 12-inch bore after the last discharge. The position of the damages are shown in the Plate by dark shading for the greatest enlargement and by thick lines for the other injuries, which are placed at the correct distances from the inner end of the barrel (A); but their vertical position could not be shown on a half section, and their *nature* could not be made visible on so small a scale. The Plate also shows the position of the shot,—1st, when in its seat; 2nd, when advanced six inches, where its base would register the highest pressures; and, 3rd, when advanced eight inches, where the rear-stud comes into "driving" bearing. The crusher-guages are shown (A) at the inner end of the bore, where the highest pressures were usually registered; (B) at the vent 12 inches from A; and (C) in the base of the shot six inches in advance of its seat. The principal injuries are:—

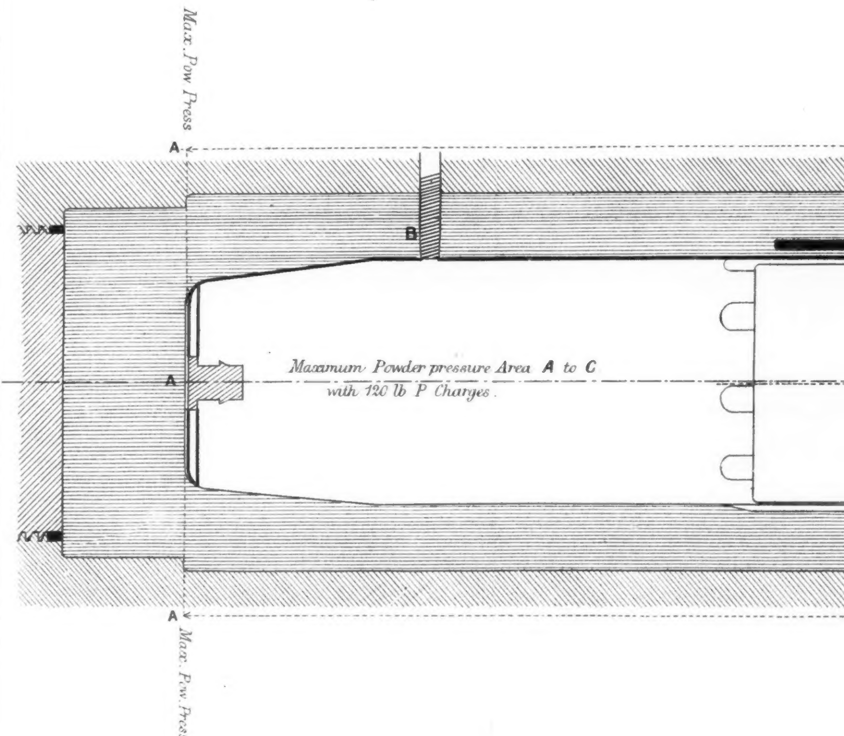
Interior

THE FIRST 12 INCH 35 TON M.L.R.

The rear stud coming int

Feb^{y} 1st 18

Scale 1/8" to an Inch.

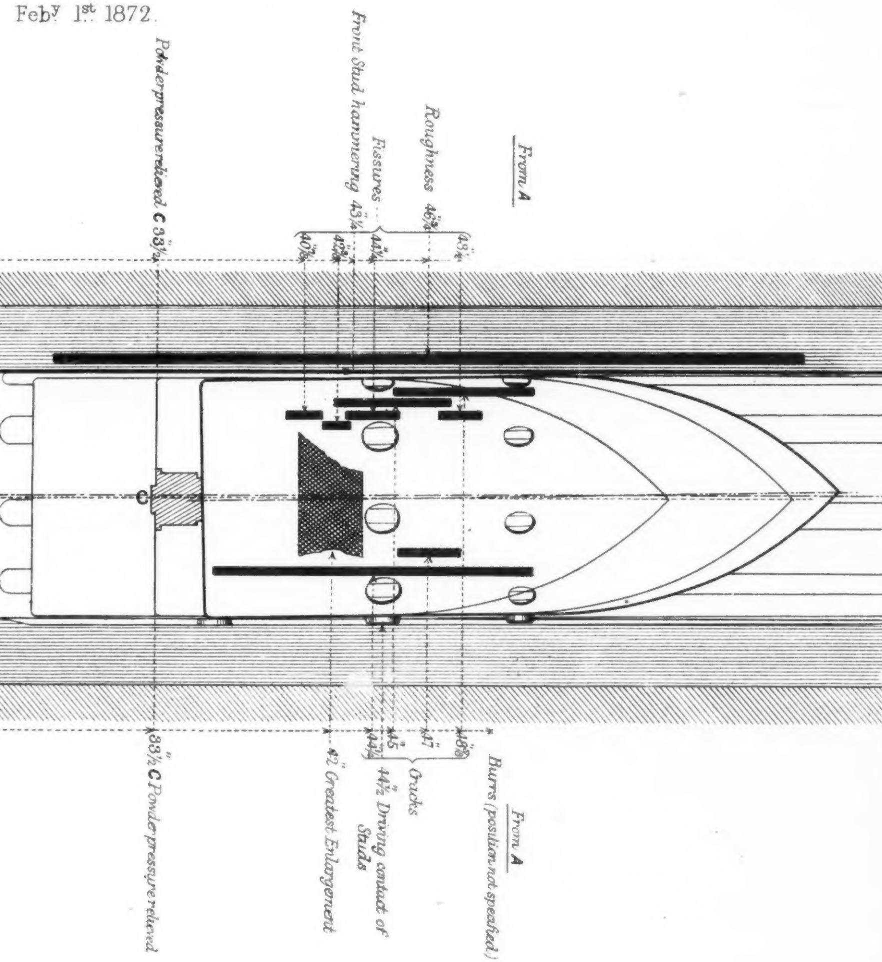


Interior of

35 TON M.L.R. GUN, AFTER 38 DISCHARGES.

...d coming into "driving" bearing

Feby. 1st. 1872.



J. Jobbins

State of the 12-inch bore, 1st February, 1872. See Plate I.	Distance from (A) inner end of bore. Extremes.	Centre.	Vertical position in the bore.
Longitudinal crack *in edge of groove*......	36½ to 52 in.	44¼ in.	R. of down
" " " "	45¼ to 52 "	48⅝ "	R. of up
" " centre of groove ..	45½ to 48½ "	47 "	L. of down
" " " "	42¼ to 47¾ "	45 "	L. of up
Slight fissures in centre of groove........	41¾ to 43 "	42⅜ "	Up
" " "	40 to 41¾ "	40⅞ "	L. of up
" " "	47½ to 49½ "	48½ "	Up
" " "	43 to 45½ "	44¼ "	Up
Greatest enlargement ·029 inches	40½ to 43½ "	42 "	Round
Roughness in lands and grooves	28½ to 65 "	46¾ "	Above
Burrs on edges of grooves	not	given	
Rear stud in seat......................	According to length of cartridge	35½ in.	Down
Rear stud in "driving" bearing		44 "	Round
Front stud in seat and hammering		43 "	Up
Maximum P. powder pressure area		0 to 33½ "	—

I should add, that it is generally understood that the report of the condition of the bore made when the gun was disabled, which is appended to the Committee's Report, does not altogether correspond in every detail with what was ascertained during the process of rebuilding. But, I am told, that the differences between the published Report and the subsequent examination, do not materially affect my argument. For no injury whatever has been discovered within the powder chamber or within the maximum powder-pressure-area, which extends to about 34 inches from the inner end of the bore where the highest pressures are registered; thereby showing that no injury whatever has resulted to the gun from the direct action of the maximum powder-pressures. Nor, as I understand, do these unpublished details vitiate the official examination made on the 1st February, 1872, the day after firing the last shot, as regards the longitudinal position of the damages, which are from 36½ to 52 inches from the point of maximum pressure at the inner end of the bore.

The "Driving" Contact of Rear Studs (Plate I).—The point where the front studs would strike, and where the rear studs come into "driving" bearing, tallies very remarkably with these injuries; for the shot moves eight inches from its seat, and attains about one-third of its velocity before the rear studs strike the "driving" edges of the grooves, the shot moving then with a striking force of 1,800 foot-tons. Now, the seat of the projectile and, consequently, the point where the rear studs come into "driving" bearing, and inflict a portion of this 1,800 foot-tons' blow, varies with the length of the cartridge. But, with the 120-lbs. charge, it is 44 inches from the point of highest pressure at the inner end of the bore. And if we suppose the operation of shearing off the rounded edges of the rear studs, and of wedging the gun-metal over the edges of the grooves, and of printing base marks

into the iron projectile, to be spread over a few inches of the shot's progress, the place in the bore where these suicidal operations would naturally be performed, corresponds with singular faithfulness to the central points of the four cracks, and the four slight fissures in the grooves, and with the maximum enlargement of the barrel.

The position of the burrs on the edges of the grooves is not given; but it is physically impossible that the rear-studs could make these burrs within the maximum powder-pressure-area, for they must then do so in rear of their own seat. It is most likely that the burrs are at, and in advance of, the point where the rear-studs strike their portion of the 1,800 foot-tons' blow upon the edges of the grooves, and commence to shear and override or wedge on the lands.

The roughness of the bore naturally begins above the seat of the base of the projectile, and therefore extends six inches within the maximum powder-pressure-area. Colonel Campbell ascribes "the great disadvantage of local scoring" to "the system" of rifling. This serious evil is caused, in the initial stages of combustion, by the rushing gases, in their effort to escape *over* the shot through the windage space, and through the wide, deep, almost-unoccupied upper grooves. This "local scoring" doubly effects the pressures, first, by striking down the base of the shot, nicely balanced on two points nearly under the centre of gravity, striking the front stud against the centre of its groove, and setting up a vertical "oblique movement of the axis of the projectile;" and, secondly, by roughening, like the bark of an elm tree, the surface which the studs have to traverse, thus impeding their exit, inducing shear and wedging, and enhancing the force of the "oblique movements" about the rear-studs.

Whatever be the cause, the position of every injury in the 12-inch bore is just in advance of the seat of the studs, outside the maximum powder-pressure-area, 3½ to 4½ feet from the point where the highest pressures were registered (See Plate I), and at a place where they would naturally obstruct the free exit of a non-centering projectile, liable to that "wriggling" action which the learned Professor of Artillery euphemistically styles an "oblique movement of the axis." Every such "roughness," "burr," "crack," and "fissure" in the grooves, is a sufficient obstructive to the exit of the soft metal studs, as they wedge their way over the lands out of the gun, to increase greatly the force of the "wriggle" natural to the shot.

The Omitted Document.—The omission from the Committee's Report of any examination of the injured studs and base-marks of the recovered 700-lbs. projectiles, is very remarkable, considering the great care displayed in registering the pressures yielded by each discharge. Had another column been added to the Practice Table, giving, if need be, a microscopic examination of the condition of the studs and projectiles on recovery, a comparison between the pressures and the resistances experienced by the escaping shot would have been most valuable. The omission is very remarkable, seeing Colonel Campbell's evidence against the studs and the rifling generally, before the 35-ton Gun Competitive Council; and what very opposite testimony was borne by Sir William Armstrong on the same occasion, as to the transcendental virtues of studs, and of that

increasing spiral which necessitates their use.* "With regard to the "studs," said Sir William, "I would point out that, in future, where "much milder powder will be used, the strain upon the studs will be "proportionately less, *because of course it is the maximum pressure which "causes the failure of the stud.*" If, then, the defender of the stud-system himself stated of this very gun that "*the maximum pressure "causes the failure of the stud,*" why was not the extent of this "failure" noted?

Moreover, the Special Committee, in recommending, last February, a method of proving heavy guns with projectiles of double weight, evince their anxiety about the stability of the studs, and their influence on the endurance of guns, by suggesting that the proof should consist of "one round of battering charge of pebble powder and projectile of "service weight, two rounds of battering charge of pebble powder and "*unstudded* projectile twice the weight of the service projectile;" and even for the lighter M.L.R. guns, the Committee recommend the suggested proof projectile to be "*unstudded,*" and the Superintendent of the Royal Gun Factories consistently agrees that, if such a mode of proving guns be adopted, "in such case *the cylinder should not be "studded.*"† Thus, it is evident that the Special Committee and the able Superintendent of the Royal Gun Factories are of one mind with regard to the effect of high pressures on the stud, and through the stud upon the gun, concurring, apparently, with Sir William Armstrong, that "*the maximum pressure causes the failure of the stud.*"

Again, in all other heavy guns rifled on this most unmechanical system, the projectiles are so injured in their efforts to wriggle their way out of their bores that they are obliged, when picked up, to be re-melted; excepting, in the case of "proof" projectiles, which have, however, to be re-studded. Seeing that the rifle-bearing in each groove is precisely the same for 115-lbs. and for 700-lbs. shot, might not a similar, not to say an enhanced, destructive action be reasonably supposed to occur in the case of 700-lbs. shot?

Surely, then, the extent of "the failure of the stud," as to its shearing and wedging, as to its non-centering, and as to its keeping the iron part of the projectile from touching the bore, ought to have been carefully recorded before running off into such phrases as "wave "pressures" and "local action," which mystify the unlearned and explain nothing. Let us exhaust scientific research into the tangible, and visible, and into every possible mechanical disturbing element, before giving the rein to fertile imaginations, and seeking refuge in inscrutable phenomena. Of course there are gas waves in the gun, but what makes these "wave pressures" to vary in intensity? When the waves of the sea overwhelm a ship, practical seamen ask not what was wrong in the waves? but what was the fault of the ship? And when "intense wave pressures" act unexpectedly upon a shot, practical gunners inquire what was wrong with the projectile?

"*The Oblique Movement.*"—In the absence of examinations of the

* See Parliamentary paper No. 308 of 1870, being the "Report of the Ordnance Council on the Proposed 35-ton Gun Competition," page 13.

† See "Extracts of Artillery Proceedings," &c., vol. x, Part II, pages 85, 86.

recovered 700-lbs. shot, they may be supposed to have had similar marks to those observed on all other recovered projectiles, which have, in consequence, to be destroyed or re-studded. Those marks generally coincide with that mechanical action of the studs, which gives rise to what the Professor of Artillery calls an "oblique movement of "the axis of the projectile."

The official work on *Ammunition*, Part II, page 57, points out that "in all Woolwich guns, both the direction and twist are given by the "bearing of the studs on the grooves, the *body of the shot never being* "*intended to come into contact with the bore;*" and, page 58, "it may be "observed that by the time the projectile reaches the muzzle of the "gun, considerable wear has taken place on the driving edges of the "studs," on the exactly *rounded* character of which all centering depends. Yet Colonel Owen rightly states that "in order to secure "accuracy of fire, *it is essential that the axis of the projectile should* "*correspond with that of the bore.*"

The studs are necessarily attached to the shot at a fixed angle; but the grooves they traverse are cut at ever-changing angles. The studs being fixed, cannot, therefore, touch the changing sides of the grooves at more than one angle, *i.e.*, at one point. The point selected for both studs to share the effort of rotation is twelve inches from the muzzle. In all other parts of the bore, this constantly changing angle in the spiral, necessitates the concentration of rotatory effort upon the rear-studs; that is to say, the length of bearing in each groove is the same, whether the weight of the shot to be rotated, be 115 lbs. or 700 lbs., or, as in guns designed, 1,200 lbs. The work to be done is vastly increased in the heavier shot, but the bearing in each groove is the same. As the studs won't stand the additional work, they shear or wear down their radial bearings, on which all centering action depends. Thus a most essential condition of all rifling is destroyed.

In its seat, the shot rests on the two studs in the lower groove, the other studs being only partially inserted into their grooves, the centre or axis of the shot is below the centre or axis of the gun, the whole of the windage is in the upper part of the bore, and no part of the projectile is in contact with the barrel except the two lower studs. These studs being nearly under the centre of gravity, the shot is balanced in unstable equilibrium, the "loading" edge of the lower studs touching the "loading" side of their grooves. All the roughnesses or scoring, which are caused by the escaping gases, are found above the seat of the projectile, and seldom occur in any gun, below its base, which is usually embedded in fouling matter. Hence, the concussion of the first part of the explosion takes effect upon and above the base. The blow from the gases in the initial stages of combustion as they escape above the shot, strikes the base down and the point up, hitting the upper groove a blow with the front stud, and setting up a vertical motion of an "oblique" character. Doubtless, the fouling matter in the gun may sometimes raise the base of the shot in its seat, admitting the gases below as well as above the projectile. Thus enveloped before starting, the resolution of forces would cause the initial movement of the shot to be upwards at the base, and down at

the point. Probably this occurs when the *centre* of a "down" groove is found cracked or fissured in the seat. But the marks and roughnesses generally found in "Woolwich" guns point to the first gases evolved from the ignition of the upper side of the cartridge, passing out above the seat, before the shot starts. It is clear that the vertical motion is the first movement initiated in the seat, and is begun during the initial stages of combustion.

If the shot were pushed gently forward for eight inches, the lower rear-stud would then touch on the "driving" side, and the other rear-studs, not being so deep in their grooves as the lower ones, would come *successively* into bearing against the "driving" edges. As the lateral bearing is at best only a ring of one-inch points, in rear of the centre of the shot, a tendency to turn upon those points sets up a horizontal motion of an "oblique" character. Any obstacle from roughnesses, enlargements, burrs, dents, fissures or cracks, which increases the friction on the rear-studs, enhances the force of the "oblique movements" about the studs. Thus, "oblique movements of the axis of the projectile" in two directions, are provided for in the mechanical action of the rear studs.

This mechanical action was thus described at the Civil Engineers' Institution, last year, by Mr. C. W. Lancaster:—"The 700-lbs. shot of the Woolwich 35-ton gun, before being fired, rested on the bottom of the bore, and had not only to be rotated by the action of the studs, but to be lifted as well, and then projected through the bore at the rate of between 1,300 and 1,400 feet per second, thus involving a double duty. When the shot rose, the bronze studs struck against the angles of the grooves. * * * * In fact, so violent was the action, that not only were there numerous instances of sheared studs, but the impress of the grooves in the gun was left upon the body of the shell, to the depth of nearly one-tenth of an inch. That, he contended, was not fair play, either to the constructors of the gun, or to the country which had to pay for it."

Mr. Bashley Britten had pointed out that "The irregular action upon the studs was practically shown by the unequal wear they frequently sustained. When all went well, the studs of recovered shot were only moderately compressed and burnished; at other times the compression was considerably greater; and frequently, even when there had been no increase of charge, the studs were found to have been jammed and ground away to one-tenth of an inch or more, affording unmistakable evidence of the violence with which they had been pressed against the bore, and of the force of the charge thus thrown upon the gun."

The front studs are intended to come into "driving"-bearing 12 inches from the muzzle, when the shot is moving with a striking force of about 6,000 foot-tons. When they fulfil this evil intention, a second set of mechanical forces come into operation. But, as there is no evidence that the front studs performed their office in the 35-ton gun, it is unnecessary here to investigate their mechanical action.

Mechanical Causes of High Pressures.—If, when in its seat, the projectile be not gently pushed, but violently struck upon and above its

base, it is evident that the important element of time will be greatly diminished, and that the obstruction resulting from these "oblique "movements of the axis" about the rear-studs, will increase in severity with the suddenness and violence of the blow. Thus, the mechanical obstruction offered to the free escape of the shot, would be more marked, and the accumulation of gases behind it be much greater:—

1. When more quick-burning, and therefore more sudden or violent powder is used, giving the wriggling shot *less time* to recover its direction.

2. When heavier powder charges are employed, also giving the wriggling shot less time to recover its direction.

3. When the temperature of the powder chamber has been highly raised by previous discharges, causing more sudden and complete combustion.

4. When the gun is so elevated that the influence of gravitation acts with greater power against the shot's escape.

5. When short shot are used in the same bore, the "oblique move-"ments of the axis" round the studs causing an accumulation of gases, are obviously much more forcible, *e.g.*, a 600-lbs. shot gives higher pressures than a 700-lbs. shot in a 12-inch bore.

6. When a hard roughened surface, with steel furrows as deep as those on the bark of an elm tree, occurs in the path of the brass stud, so that the gun-metal may catch in the furrows, and the "oblique move-"ment of the axis of the projectile" around the rear-stud be intensified, then the escape of the shot would be more difficult, and an accumulation of gases would take place in its rear (see Plate I).

These mechanical movements are naturally erratic, the "wriggling" being more or less severe, according to various conditions of an accidental character. Of course the more severe wriggles cause the highest pressures, and mark the bore most severely at the point of obstruction. Hence, a careful study of the marks within the gun and upon the projectile, is essential to any reliable deductions from tabulated powder-pressures.

The "Milder Powders" used.—Only two kinds of, what Sir William Armstrong calls, "milder powder," were used in the 35-ton gun, viz., Waltham Abbey P. and Belgian P. P. stands for "pebble" and "pellet" powders indifferently, both being similar in character; but a military critic says that the kind of P. used with the 35-ton gun was "pebble-powder."

The manufacture of gunpowder has reached such perfection that its explosive force can be perfectly controlled with exactitude and uniformity, being varied at will to ignite rapidly or slowly, and to burn slowly or quickly. Slow burning is, of course, characteristic of the slow action "milder powder" used in the 35-ton gun. Quick-burning distinguishes the violent "brutale" powder formerly in use. This change is managed by altering the granulation and density of the same thoroughly incorporated ingredients. In the P. powder, the mass of ingredients is divided into large irregular pebbles, shapely pellets, or split pellets, through the wide interstices of which the flame rushes freely, igniting all the pebbles rapidly; but, once ignited, the large

pebble takes time to consume, slowly burning from the outside to its centre. If the pebble be porous, the flame will penetrate to its centre more rapidly than if it be more closely pressed, *i.e.*, more dense.

On the other hand, where the mass of thoroughly incorporated ingredients is divided into smaller grains, these lie closer together in the cartridge, and the flame cannot get between the grains from the point of ignition to the extremities of the charge so rapidly as when there are wide interstices. When, however, the flame does touch the outside of the smaller grain, its centre is soon reached, making combustion very rapid. The R.L.G. belongs to this type of quick-burning, violent powder, and was not, therefore, used in the 35-ton gun.

The Belgian P. was more violent in its action than our W.A.P. This arose, I suppose, either from the ingredients being mixed in different proportions, or from the pebbles being more porous, and thus consuming more rapidly.

Diminution of violence is not the only result of enlarging the grains. The gases evolved from the combustion of slow-burning pebbles operate more gradually and for a longer period upon the shot, only attaining their maximum force, in the case of the 8-inch gun, when the projectile has moved 6 inches; whilst the quick burning R.L.G. powder attains double the force before the studded shot moves one quarter of an inch. But, though only half the pressure is evolved by the slow-burning P., it sticks to its work longer, and results in slightly greater velocity to the shot. Moreover, this more gradual application of force to the projectile, with half-pressure in the gun, enables larger charges to be safely employed, with increased velocity and striking force.

The able Superintendent of the Royal Gun Factories, however, remarks "that the very heavy charges of pebble powder, although they may "not give the same pressures as the former charges of R.L.G., still "really do much more real damage to the guns, and will render the "necessity of re-venting, and, indeed, of re-tubing the guns, much "more frequent."*

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* "Extracts of Artillery Proceedings," &c., vol. x, Part II, page 101.

† "Journal of the Royal United Service Institution," vol. xv, No. 64, page 312 et seq.

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isting and unalterable laws of nature. For example, when Robins, the father of scientific gunnery, estimates the maximum pressure evolved from ignited gunpowder at 6·7 tons per square inch; Gay-Lussac at 14·3 tons; Piobert at 64 tons; Bunsen and Schischkoff at 30 tons; Professor Bloxam at 62 tons; and Captain Noble of Elswick at 40 tons, may we not ask those who rest satisfied with such phrases as "wave pressures," "local action," &c., to examine more closely into the disturbing causes which produce the phenomena disguised under the above phraseology?

PRACTICE WITH 11·6 INCH 700-LBS. SHOT (TABLE I, pp. 16 and 17).

Let us consider the mechanical forces at work to influence the powder pressures registered in the 11·6-inch bore. The Practice Table shows that the registering arrangements were not so complete for the 35 rounds with this calibre, as for the 38 discharges from the 12-inch barrel. In 23 rounds, the pressure at the bottom of the bore, where it is usually highest, was not taken; in three rounds, no pressures at all were registered; on four occasions, the cartridge was ignited at the rear-end and twice at the front, the remaining 29 charges being ignited at the usual service position, viz., 12 inches from the bottom; and in three instances, the less slow-burning, and therefore less mild, Belgian P. powder was employed. Eliminating such disturbing elements, we may still find a good many charges fired under precisely similar conditions, which, had the mechanical obstructions to the escape of the projectile been exactly alike, ought to have produced similar results.

As compared with the practice from the 12-inch barrel, the maximum pressures registered in the smooth unroughened 11·6-inch bore, were, as we should expect, more eccentric, and, therefore, higher in proportion to the resulting velocities and striking force. Obviously, for the gases to expand to equal bulks, it is necessary that the shot should move further from its seat in the 11·6-inch bore than in the 12-inch barrel. But the resistance offered by the lower studs on which the shot rest, is intensified by the extra rapidity and suddenness of the force applied to them. Hence the shot, being of the same weight, and of nearly the same length, we should expect, with the same P. charges, a more powerful, and therefore, more obstructive, "oblique movement "of the axis of the projectile" about the rear-studs in the smaller bore, causing a more perfect combustion of powder and a greater accumulation of gases.

Rear-ignition in 11·6-*inch Bore.*—Comparing the two 75-lbs. P. charges ignited at the vent (Nos. 1·2) with the two (Nos. 9·10) ignited at the rear, the former appears to have resulted in the best powder combustion; but the resulting energy was a thousand foot-tons *less* than that evolved from a somewhat less base-pressure in the 11·6-inch bore (No. 31), and in the 12-inch barrel (No. 1·3·5·9·11). A vent-ignited 75-lbs. P. charge behind a shorter 600-lbs. shot, gave less expulsive pressure (16·6 tons) with 72 feet more velocity; and, according to the anomalous performances of studded shot, we should expect

less pressure behind the heavier 700-lbs. shot. Instead of following this "rule of contrary," No. 2 gives a higher pressure than with the lighter shot, showing that something unusual occurred, and inclining us to believe that, but for this irregularity, it ought to have been less than Nos. 9·10, *i.e.*, less than 14 tons per square inch.

This idea is confirmed by a comparison of the two 110-lbs. P. charges ignited at the rear (Nos. 18 and 19), with Nos. 11 and 13 ignited at the vent, when the opposite effects resulted. The pressure on the projectile was nearly $2\frac{1}{2}$ times *greater* when ignited at the rear (and not less as with the 75-lbs. charges); but no adequate increase of striking force resulted from this $2\frac{1}{2}$ times extra expulsive pressure, showing that this extra explosive powder did not arise solely from the point of ignition, but that extra impediments to escape were experienced by the 18th and 19th projectiles.

Front-ignition in 11·6-*inch Bore.*—Front-ignition would appear to have caused a more perfect combustion of 110-lbs. charges than ignition at the vent. But it is simply absurd to suppose that front-ignition accounts for 13 tons per square inch extra expulsive pressure in No. 14, when the striking force developed was very slightly increased; and the five extra tons pressure per square inch upon the 12th projectile, was evidently caused by the absorption of *seven hundred foot-tons* of energy within the gun as compared with Nos. 11·13.

It may be questioned by some whether this extra expulsive pressure was the cause or the effect of obstructive movements in the projectile, as changing the points of ignition did undoubtedly alter, in some degree, the relative conditions. Therefore, the effects of the "oblique "movements of the axis of the projectile" about its studs could not be exactly predicated from these comparisons alone.

Belgian P. Charges in the 11·6-*inch Bore.*—The pressures and velocities registered from the three Belgian P. charges may be compared together, but cannot be compared with those of W.A.P., as it is well known that the more quick-burning powder operates for a shorter time upon the shot, and is productive, therefore, of lower velocities. It may, however, be noted that when 49·1 tons expulsive pressure were exerted against each square inch of the base of the projectile, *less* velocity and work resulted than when 46 tons pressure was registered, both charges being Belgian P. ignited under similar conditions, except that, perhaps, the chamber was warmer when the *smaller* pressure occurred.

The W.A.P. Charges in the 11·6-*inch Bore.*—Eliminating all exceptional conditions, it is evident that the velocity and striking force of projectiles fired under identical circumstances ought, when the same kind of powder is used, to bear a constant relation to the pressures exerted upon their bases. Where this relation is inconstant, the lowest expulsive pressure which gives the highest velocity, may be fairly taken as the nearer approach to the normal results to be expected from that charge with that kind of shot, as also the case of least "wriggling" obstruction to the exit of a studded projectile.

The 31st round would, at first sight, appear to be the normal 110-lbs. W.A.P. charge, as it gives the highest velocity with

TABLE I.—PRACTICE WITH THE 11·6-INCH, 35-TON M.L.R. GUN.

STUDDED shot, 700 lbs. The pressures were determined by crushers fitted by means of a copper cup at the bottom of the bore (A), by a screw gauge inserted instead of the vent-plug (B), and by a gauge screwed into the base of the projectile (C). After the 8th round, the gun was fired by an electric tube placed in the cartridge at 12 inches from the bottom, the wires passing through a groove in the shot to the muzzle.

Date of the discharge.	No. of the round.	Powder charge.		Observed velocity		Maximum pressure by crusher-gauge in tons per square inch.			Striking force at 110 feet in foot-tons.	Point of ignition of cartridge.	State of the bore. (*Powder chamber uninjured.*)
		Brand.	Weight.	at 110 feet.	at 132 feet.	A. Axis, or end of bore.	B. Vent, or 12 in. from end of bore.	C. Base of shot when about 33½ in. from end of bore.			
			lbs.	feet.	feet.						
Jan. 13, 1871..	1	W.A.P., May 9, 1870	75	1,163	not taken	not taken	not taken	not taken	6,567	Service	Before the Experiment:— Bore clear and polished. After 6th round:— Driving edges of the grooves slightly worn, specially in L. of Up., 40¼ to 63 in. from A. Slight roughness by gas, 27½ to 49½ in. from A.
"	2	" "	"	1,163	"	"	"	17·1	6,567	"	
Jan. 14, 1871..	3	" "	100	1,261	"	"	"	not taken	7,718	"	
"	4	" "	"	1,237	"	"	"	25·4	7,435	"	
Jan. 16, 1871..	5	" "	120	1,350	"	"	"	not taken	8,852	"	
"	6	" "	"	1,364	"	"	"	46·3	9,026	"	
Jan. 18, 1871..	7	" "	110	1,303	"	"	"	31·8	8,242	"	After 8th round:— Maximum enlargement, ·007 in. at 13½ in. from A.
"	8	" "	130	1,348	"	"	"	63·7	8,816	"	
Feb. 2, 1871 ..	9	W.A.P., Dec. 21, 1870	75	1,091	"	"	15·2	13·9	5,781	Rear	
"	10	" "	"	1,090	"	"	16·4	13·1	5,772	"	
	11	" "	110	1,240	"	"	19·8	20·8	7,464	Service	

,,	12	,, ,, ...	,,	1,183	,,	,,	26·6	25·7	6,792	Front	
,,	**13**	,, ,, ...	,,	**1,244**	,,	,,	**18·8**	**19·2**	**7,508**	**Service**	
Feb. 3, 1871 ..	14	,, ,, ...	,,	1,245	,,	,,	31·8	33·8	7,521	Front	
,,	15	,, ,, ...	120	1,277	,,	,,	16·4	20·7	7,911	Service	
,,	16	,, ,, ...	,,	1,251	,,	,,	18·8	26·3	7,599	,,	After 20th round:— Roughness by gas increased in depth 25¼ to 61¼ in. from A. Greatest depth in L. of Up. Maximum enlargement, ·024 in. at 34¼ to 40¼ in. from A.
,,	17	W.A.P., May 16, 1870	,,	1,300	,,	,,	28·6	40·4	8,206	,,	
,,	18	W.A.P., Dec. 21, 1870	110	1,277	,,	,,	34·3	47·9	7,911	Rear	
,,	19	,, ,, ...	,,	1,274	,,	,,	38·6	48·3	7,880	,,	
,,	**20**	W.A.P., { May 16, 1870, 41 lbs. / July 29, 1870, 79 lbs. }	**120**	**1,353**	,,	,,	**20·0**	**21·7**	**8,883**	**Service**	
April 19, 1871 .	21	W.A.P., Oct. 18, 1870..........	110	1,077	,,	27·6	20·3	26·0	5,637	,,	
,,	*22*	*Belgian P., March* 1871........	,,	*1,288*	,,	*31·0*	*31·0*	*49·1*	*8,047*	,,	
,,	23	W.A.P., Oct. 18, 1870..........	,,	1,151	,,	not taken	20·2	24·5	6,433	,,	
,,	*24*	*Belgian P., March* 1871........	*	*1,328*	,,	,,	*44·2*	jammed†	*8,557*	,,	After 29th round:— The principal enlargement is, from ·015 in. at 28¼ in. from A to ·029 in. at 43¼ in. from A. Maximum enlargement, ·033 in. at 37¼ in. from A., *i.e.*, about four inches outside the max. pow. press. area.
,,	25	W.A.P., Oct. 18, 1870	,,	1,157	,,	,,	20·8	23·5	6,494	,,	
,,	*26*	*Belgian P., March* 1871........	,,	*1,297*	,,	*37·6*	*29·8*	*46·0*	*8,165*	,,	
April 20, 1871 .	27	W.A.P., Oct. 18, 1870	115	1,279	,,	24·4	21·6	25·2	7,934	,,	
,,	28	,, ,, ...	,,	1,271	,,	25·2	23·4	30·2	7,839	,,	
,,	**29**	,, ,, ...	,,	**1,271**	,,	**23·2**	**19·8**	**23·4**	**7,839**	,,	
May, 9, 1871 ..	30	,, ,, ...	110	1,249	1,243	24·2	19·6	20·6	7,573	,,	N.B.—No examination took place after the 35th round, and before boring out all the roughnesses of gas, burrs on the edges of the grooves, &c., in converting the 11·6 in bore into a 12-inch gun.
,,	31	,, ,, ...	,,	1,248	1,251	24·8	21·6	16·8	7,560	,,	
,,	32	,, ,, ...	,,	1,236	1,244	26·0	21·8	22·2	7,420	,,	
,,	33	,, ,, ...	115	1,226	1,277	28·6	22·2	30·8	7,295	,,	
,,	34	,, ,, ...	,,	1,222	1,273	26·8	22·4	30·2	7,246	,,	
,,	35	,, ,, ...	,,	1,148	1,273	32·8	26·8	31·8	6,393	,,	

* Charge doubtful. † Pressure must have exceeded 60 tons.

the lowest expulsive pressure, but I am inclined to doubt the accuracy of the registered pressure on the base, as it is so much less than that which occurred at the vent. Therefore, the 13th round would appear to be the normal 110-lbs. W.A.P. charge, giving, with 19·2 tons base-pressure on the square inch, a resulting blow of 7,508 foot-tons at 110 feet from the muzzle. These normal results appear to correspond very fairly with Nos. 11, 30, and 32. But contrast the normal 110-lbs. W.A.P. charge, No. 13, with No. 4, where six extra tons expulsive pressure per square inch, with 100 lbs. of powder, gave a less blow; with No. 21, in which 1,829 foot-tons of work were absorbed by the escaping projectile, causing the crusher-gauge to go up seven extra tons; with No. 23 and 25, where the escaping projectiles absorbed in the "oblique movement of their axes" about the rear-studs, upwards of a thousand foot-tons of work, causing the gases to register 5 and 4 tons extra pressure; and with No. 7, where 12 extra tons per square inch on the base only produce about 700 foot-tons greater blow. What must have been the wriggling and stud-wedging in the gun and the condition of the studs which absorbed all this useful work?

It will be observed that Nos. 21, 23 and 25 were of the same brand, yet No. 21 projectile absorbed in its "oblique movements" within the gun 857 foot-tons of work more than that absorbed by No. 25, causing the gases to accumulate to 2½ tons greater expulsive pressure against its base.

Again, No. 29 approached nearest to the normal of the 115-lbs. charges, for its projectile would have struck a 7,839 foot-ton blow, as the result of 23·4 tons pressure per square inch upon its base. A blow of identical force was produced by nearly seven tons more base-pressure on the square inch, in No. 28. Whilst a comparison of the last round (No. 35)* with the normal 115-lbs. charge (No. 29) shows the projectile absorbing 1,446 foot-tons of work, causing the highest accumulation of gases registered with any similar charge. Indeed, comparing the first three 115-lbs. charges with the last three, I am inclined to think some roughening of the grooves must have taken place in advance of the seat of the studs subsequent to the last examination. The means of these 115-lbs. charges show clearly that the diminution of striking force produced an accumulation of gases in the gun. They are:—

115-lbs. W.A.P. 11·6-inch charges.	Mean velocity.	Mean pressure at			Mean striking force.
		Axis.	Vent.	Shot.	
	feet.	tons.	tons.	tons.	foot-tons.
Nos. 27, 28, 29 .... =	1,274	24·3	21·6	26·3	7,871
Nos. 33, 34, 35 .... =	1,199	29·4	23·8	30·9	6,978

* This No. 35 may possibly be a typographical error. But the Report throws little or no light upon the table, and the figures can only be accepted as given.

The normal 120-lbs. charge is the 20th, the "oblique movement of "the axis of the projectile" about the rear-studs, being evidently *less* severe than in the case of the succeeding 115-lbs. charges, and only little more so than with the normal 110-lbs. charge (No. 13). Probably No. 20 is an accidental instance in which the shot escaped with a very slight "oblique movement," and its studs without any shear or wedging, and perhaps it may have nearly centered itself in the bore. Such a phenomenon would explain the fact that the shot escaped with 8,883 foot-tons of striking force in it, having sustained a base-pressure of only 21·7 tons. If the axis of every escaping projectile had corresponded with the axis of the piece, then every accretion of powder gases in the rear would have produced an increased striking force. But, on the contrary, with only one exception in which more than double pressures occurred (No. 6), every weaker blow with 120-lbs. charges (except No. 15)* was attended with higher accumulations of gases. Thus, as compared with the normal 120-lbs. charge, the 17th projectile absorbed 677 foot-tons of work, causing the gases to rise to nearly double the pressure; the 6th shot, projected by 25 ton per square-inch greater pressure, attained only 143 foot-tons greater energy; whilst 130 lbs. of similar powder (No. 8) exerted nearly three times the pressure of the normal 120-lbs. charge upon its projectile, yet resulted in 67 foot-tons *less work*. Now, Sir Wm. Armstrong says, "*of course, it is the maximum pressure* "*which causes the failure of the stud*," and the late Ordnance Select Committee reported that "*the gun rifled on the French* ('*Woolwich*') "*system has decidedly the lowest velocities.*" May we not reasonably ask when this maximum pressure of 63·7 tons was registered on the base with low velocity in the projectile, what was the extent of "the "failure of the stud"? and what became of the expulsive force developed by the 130 lbs. of similar powder? As the bore within the maximum powder-pressure-area was not strained, where was the power of these gases absorbed? The "local action" was on the base of the shot, where did the shot convey it to, as it was not carried out of the gun?

Sir Henry Storks "has never been satisfied with the discrepancies "as to the amount of pressure produced by a comparatively small in-"crease in the charge of powder." The expulsive pressure per square inch given by the normal 120-lbs. charge was 21·7 tons on the base of the projectile, that given by the 130-lbs. charge was 63·7 tons. The same powder was employed under identical conditions. When 130-lbs. charges are exploded in torpedoes, in mines, or anywhere except in a French-rifled gun with short rifle-bearings, is the explosive force evolved, found to be three times that of 120-lbs. charges? It is the fault of the powder-manufacturer say some—but is it found that small charges of similar powder produce these anomalous results? And do not the

* Cases like those of No. 15, where a lower base-pressure was productive of a lower velocity, may arise from the "oblique movement" or wriggle taking place nearer the muzzle, as when the front studs come violently into bearing 12 inches from the outer end of the bore. Then the velocity would be checked, but the accumulation of gases would not, except in very severe wriggles, exceed the maximum powder pressure which had already been registered after the shot had moved 6 inches.

Committee report that "when *any description* of powder is increased "beyond a certain limit," these "discrepancies as to the amount of "pressure produced" always occur?

Perhaps, say others, the pebbles may have fallen evenly together in the cartridge, so as to fit like bricks in a wall, leaving no interstices between;—but, in that impossible case, the shot would be driven out slowly long before the flames reached the centre of the compact mass, and the crusher in its base would register a lower, not a higher pressure. It's all those "intense wave pressures," say others;—but, why do "gas waves" vary in height to three times their usual altitude? Grant that the injuries sustained by every recovered and broken-up projectile are inflicted within the gun; that there is "an oblique move-"ment of the axis of the projectile" about the rear-studs; that "it is "the maximum-pressure which causes the failure of the stud;" and that, in short, mechanical forces are at work during the exit of the shot, checking its progress, and causing an unwonted accumulation of gases in its rear, and the greater part of the phenomena is solved.

PRACTICE WITH 12-INCH 700-lbs. SHOT (TABLE II, pp. 22 and 23).

The Practice Table of the 12-inch barrel is very complete as regards both the pressures and the examinations of the bore, though, as before, we have no account of the injuries sustained by the several projectiles. The increase of calibre was, of course, attended with diminished pressures from similar charges. The bore, however, began to develop at an early stage those roughnesses, burrs on the edges of the grooves, and enlargements in front of the seat of the studs, which, by obstructing the path of the studs, intensify the "oblique movement of the axis "of the projectile" about the rear ring, thus checking its escape and causing an accumulation of gases in the powder chamber. This can be very clearly traced in Table II by comparing the earlier with the later pressures, and observing how these are generally attended with an absorption of useful work within the gun. This table is, in this respect, far more instructive than the less perfectly-recorded practice with the 11·6-inch bore.

The Belgian 12-inch P. Charges.—The seven quicker-burning Belgian P. charges naturally gave high pressures which acted for shorter periods upon their projectiles, and therefore produced relatively inferior results; but these pressures ought to have been as regular in the gun as they would have been in a shell, in a mine, or in a torpedo, unless some forces operated in the gun which find no place in the shell, in the mine, or in the torpedo. The bore presenting a polished surface when the three 110-lbs. Belgian P. charges were fired, the irregularities are very remarkable; still, we find the first one (No. 2 discharge) yielding six tons more pressure than the other two, without any adequate increase of striking force.

The four 115-lbs. Belgian P. charges acted more violently on the wriggling shot, giving them less time to recover their true direction. No. 10 shot appears to have suffered least, as it took away with it 8,936 foot-tons of useful work as the result of 26·4 tons' expulsive

pressure. But the 12th and 14th shot found or formed a slight enlargement of the bore at the point where their rear-studs come into bearing and the front-studs hammer, which would naturally intensify "the oblique movement of the axis of the projectile" about the rear-ring of studs; and, accordingly, the gases accumulated behind these shot, to the extent of 23 and 21 tons per square inch extra expulsive pressure respectively, without any noteworthy increase of velocity and striking force. There were "intense wave pressures" no doubt, but the powder and all its apparent conditions were alike, and you might as well blame the "waves of the sea" for overwhelming a badly-ballasted ship, as say that this vast absorption of expulsive force within the gun was caused by "wave pressures."

The Waltham Abbey 12-inch P. Charges.—The "milder" slow-burning W.A.P. charges evinced at least four clearly-defined effects :—

1st. The pressure on the base of the shot was, generally, several tons less than that registered at the inner end of the bore, and, in the higher ones, a little more than that at the vent.

2nd. All the earlier discharges, when the 12-inch bore was fresh from the factory, gave very regular and low pressures, with very fairly corresponding striking forces.

3rd. When the bore was roughened, burred, enlarged, fissured and cracked just in front of the seat of the studs, the pressures were very high and very irregular, with an utter lack of correspondence in the resulting striking forces.

4th. The space within which the maximum powder pressure is confined by the projectile, is, except as to erosion over the base of the shot, wholly uninjured from the intense pressures; whilst the centres of the injuries are upwards of 3½ feet from the point where the maximum powder pressures were registered, and correspond, as nearly as possible, with that point in the bore where the front-studs would strike, and where the rear-studs were driven into bearing, and where "the oblique movement of the "axis of the projectiles" about their rear rings of studs would necessarily be most intense. (See Plate I.)

To make these points quite clear, Table III has been formed, in which are given, 1st, the results with each charge when the "oblique "movement of the axis of the projectile" was at a minimum, being the least objectionable or normal mechanical condition; 2nd, the mean results when the bore was fresh from the factory; and 3rd, the mean results when the bore was roughened, burred, fissured, cracked, and enlarged by the front-studs and in front of the point of driving contact of the rear-studs. (See Plate I.)

Cause and effect are brought out very clearly in Table III, establishing a *primâ facie* case against the projectile, which a more minute examination of the detailed Table II fully justifies.

TABLE II.—PRACTICE WITH THE FIRST 12-INCH 35-TON M.L.R. GUN.

STUDDED shot, 700 lbs. The pressures were determined by crushers fitted by means of a copper cup at the bottom of the bore (A), by a screw-gauge inserted instead of the vent-plug (B), and by a gauge screwed into the base of the projectile (C). The gun was fired by an electric tube placed in the cartridge at 12 inches from the bottom, the wires passing through a groove in the shot to the muzzle.

Date of the discharge.	No. of the round in all.	No. of the 12-inch discharge.	Powder Charge.		Observed velocity.		Maximum pressure by crusher-gauge in tons per square inch.			Striking force at 110 feet in foot-tons.	State of the 12-inch Bore. (*Powder Chamber uninjured*). See Plate I.
			Brand.	Weight.	At 110 feet.	At 132 feet.	A. Axis, or end of bore.	B. Vent, or 12 inches from end of bore.	C. Bases of shot, when about 33½ in. from end of bore.		
				lbs.	Feet.	Feet.					
Oct. 19, 1871.	36	1	W.A.P., Oct. 18, 1870........	110	1,274	1,266	20·2	20·0	17·2	7,880	Before the Experiment:— Bore clear and polished.
"	*37*	*2*	*Belgian P., March, 1871......*	"	*miss*	*1,301*	*28·4*	*23·6*	*30·5*	*8,220*	
"	38	3	W.A.P., Oct. 18, 1870	"	1,265	1,269	20·0	19·2	16·8	7,768	
"	*39*	*4*	*Belgian P., March, 1871......*	"	*1,299*	*1,302*	*23·6*	*21·8*	*24·2*	*8,191*	After 12th Discharge:—
"	40	5	W.A.P., Oct. 18, 1870	"	miss	1,272	20·2	19·8	17·6	7,852	Maximum enlargement ·009 in.,
"	*41*	*6*	*Belgian P., March, 1871......*	"	*1,296*	*1,306*	*24·8*	*21·2*	*24·4*	*8,154*	43¼ to 46½ inches from A, *i.e.*, 10
"	42	7	W.A.P., Oct. 18, 1870........	115	miss	1,289	23·2	19·6	19·8	8,060	inches outside the area of maximum powder pressures, and ex-
"	*43*	*8*	*Belgian P., March, 1871......*	"	*1,316*	*1,323*	*30·4*	*23·2*	*29·0*	*8,408*	actly where rear-studs come into
Oct. 20, 1871.	44	9	W.A.P., Oct. 18, 1870	"	1,291	1,292	22·0	19·8	15·8	8,090	"driving" bearing, and where
"	*45*	*10*	*Belgian P., March, 1871......*	"	*miss*	*1,357*	*28·0*	*23·2*	*26·4*	*8,936*	front studs hammer.
"	46	11	W.A.P., Oct. 18, 1871........	"	1,230*	1,242*	23·2	20·0	17·4	7,344*	
"	*47*	*12*	*Belgian P., March, 1871......*	"	*miss*	*1,360*	*48·0*	*34·6*	*49·6*	*8,973*	
											After 33rd Discharge:— Longitudinal crack *in edge of groove*, R. of D., 38 to 52 in. from A.
Oct. 24, 1871.	48	13	W.A.P., Oct. 18, 1870........	"	1,285	miss	21·7	20·4	20·8	8,015	Longitudinal crack *in edge of groove*, R. of Up., 46 to 52 in. from A.
"	*49*	*14*	*Belgian P., March, 1871......*	"	*1,358*	*miss*	*43·8*	*32·9*	*47·2*	*8,949*	Longitudinal crack in centre of
"	50	15	W.A.P., Oct. 18, 1870........	120	miss	1,312	20·0	18·4	18·0	8,352	groove, L. of D., 45¾ to 47¾ in. from A.
"	51	16	" "	"	1,311	miss	27·6	20·8	23·4	8,341	Longitudinal crack in centre of

„	52	17	„ „	„	miss	1,305	25 ·6	21 ·2	23 ·4	8,264	groove, L. of Up., 43 to 45½ in. from A. Maximum enlargement, ·022 in., 40¼ to 43¼ in. from A. Roughness in lands and grooves by gas, 28¼ to 65 in. from A. Up. Burrs on the edges of the grooves. N.B.—All these injuries (except the roughness by gas) are outside the max. pow. press. area and about where the rear-studs come into "driving" bearing, and where front studs hammer.
Nov. 23, 1871.	53	18	W.A.P., Nov. 11, 1870	115	1,283	1,286	28 ·0	20 ·8	29 ·2	7,991	
„	54	19	„ „	120	1,322	1,324	20 ·8	21 ·6	25 ·4	8,488	
„	55	20	„ „	„	1,312	1,317	32 ·4	25 ·8	31 ·6	8,352	
„	56	21	„ „	„	1,337	1,341	40 ·6	31 ·6	41 ·8	8,674	
Nov. 24, 1871.	57	22	W.A.P., Nov. 7, 1870........	„	1,341	1,343	28 ·8	22 ·6	29 ·0	8,733	
„	58	23	„ „	„	1,314	1,312	28 ·8	23 ·2	31 ·0	8,382	
„	59	24	W.A.P., Nov. 9, 1870........	„	1,352	1,349	38 ·8	29 ·8	39 ·0	8,876	
„	60	25	W.A.P., Nov. 7, 1870........	„	1,332	1,334	38 ·4	28 ·6	37 ·4	8,615	
Dec. 1, 1871.	61	26	W.A.P., Oct. 7, 1870, No. 64..	„	1,364	1,366	46 ·8	35 ·2	45 ·4	9,026	
„	62	27	„ „ ..	„	1,360	1,358	66 ·0	42 ·6	53 ·2	8,973	
„	63	28	W.A.P., June 24, 1871, No. 11	„	1,336	1,334	44 ·6	34 ·2	46 ·8	8,662	
„	64	29	„ „ „	„	1,334	1,328	37 ·6	27 ·0	39 ·6	8,639	
„	65	30	W.A.P., No. 64	115	1,319	1,319	43 ·0	30 ·8	43 ·2	8,442	
„	66	31	„ „	„	1,306	1,305	48 ·4	28 ·8	43 ·2	8,276	
„	67	32	W.A.P., No. 11	„	1,323	1,318	44 ·0	30 ·6	41 ·6	8,500	
„	68	33	„ „	„	miss	1,318	42 ·6	28 ·4	41 ·8	8,431	
Jan. 25, 1872.	69	34	W.A.P., No. 64	110	1,291	1,293	33 ·0	17 ·8	27 ·1	8,090	After 38th Discharge:— Longitudinal crack *in edge of groove*, R. of D., 36½ to 52 in. from A. Longitudinal crack *in edge of groove*, R. of Up., 45¼ to 52 in. from A. Longitudinal crack in centre of groove, L. of D., 45½ to 48¼ in. from A. Longitudinal crack in centre of groove, L. of Up., 42½ to 47¾ in. from A. Slight fissures in centre of groove, Up., 41¾ to 43 in. from A. Slight fissures in centre of groove, L. of Up., 40 to 41¼ in. from A. Slight fissures in centre of groove, Up., 47¼ to 49¼ in. from A. Slight fissures in centre of groove, Up., 43 to 45½ in. from A. Maximum enlargement, ·029 in., 40½ to 43½ in. from A. Roughness in lands and grooves, by gas, 28¼ to 65 in. from A. Up. Burrs on edges of grooves. N.B.—The rear-studs come into "driving" bearing, and the front stud hammers about 43 in. from A, near where the greatest enlargement and all the cracks and fissures occur. The max. pow. press. area extends to about 34 inches from A, and is wholly uninjured, except for a few inches, by gas roughening.
Jan. 26, 1872.	70	35	W.A.P., No. 11	„	1,310	1,314	27 ·8	20 ·8	27 ·2	8,330	
Jan. 29, 1872.	71	36	„ „	„	1,287	miss	26 ·6	19 ·8	24 ·4	8,037	
Jan. 30, 1872.	72	37	W.A.P., No. 64	„	1,303	1,315	32 ·8	20 ·8	28 ·0	8,242	
Jan. 31, 1872.	73	38	„ „	„	1,293	1,298	36 ·4	25 ·8	33 ·0	8,118	

* Doubtful.

TABLE III.—COMPARISON BETWEEN DISCHARGES FROM THE NEW AND FROM THE ROUGH 12-INCH BORE.

Number of 12-inch discharge, 700-lbs. studded shot.	W.A.P. charge.	Mean maximum pressure per square inch. A. Inner end of bore.	B. Vent, 12 inches from end of bore.	C. Base of shot when about 33½ inches from end of bore.	Mean observed velocity at 110 feet.	Mean striking force.	State of the 12-inch bore. (*Powder chamber uninjured.*) See Plate I.
	lbs.	tons.	tons.	tons.	feet.	foot-tons.	
Normal, No. 1........	**110**	**20·2**	**20·0**	**17·2**	**1,274**	**7,880**	Clear and polished.
1, 3, 5	„	20·1	19·7	17·2	1,272	7,853	
34, 35, 36, 37, 38	„	31·3	21·0	27·9	1,297	8,165	Grooves roughened, burred, fissured, cracked, and enlarged in front of the seat of the studs.
Normal, No. 9........	**115**	**22·0**	**19·8**	**15·8**	**1,291**	**8,090**	Very slight enlargement in front of the seat of the studs.
7, 9, 11, 13............	„	22·5	19·95	18·5	1,274	7,880	
30, 31, 32, 33	„	44·5	29·7	42·45	1,314	8,382	Grooves roughened, burred, cracked, and enlarged in front of the seat of the studs.
Normal, No. 15	**120**	**20·0**	**18·4**	**18·0**	**1,312**	**8,352**	Slight enlargement in front of the seat of the studs.
15, 16, 17	„	24·0	20·1	21·6	1,309	8,319	
26, 27, 28, 29..........	„	48·7	34·7	46·2	1,349	8,832	Grooves roughened, burred, cracked (?), and enlarged in front of the seat of the studs.

The first three 110-lbs. W.A.P. discharges (Nos. 1, 3, 5) were so regular in their action, that the projectiles would appear to have slid over the polished surface of the bore with uniformity of movement; whilst the last four 110-lbs. discharges (Nos. 34, 35, 36, 37, 38) had no relation whatever to the first three, or to each other. No. 1 drove the projectile out by 17·2 tons expulsive pressure on the square inch, No. 38 did so with nearly double that pressure, and yet the resulting blow would only have been 238 extra foot-tons. There was thus, evidently, an impediment to the shot's escape somewhere; and such impediment caused the gases to accumulate in its rear to nearly double their wont. An impediment is found in the bore at the point of "driving" contact of the rear-studs sufficient to set up an intense "oblique movement of "the axis of the projectile" round the studs. (See Plate I.)

Now, 110 lbs. W.A.P. powder is the maximum service charge to which this gun is reduced. *If 38 horizontal discharges, spread over one hundred and four days, upwards of 24 hours elapsing between each of the last four rounds, doubles the pressures,—what might occur if, at the end of three years' training practice at sea, firing eight rounds every three months, or 96 discharges in all, the ship had to go into a naval bombardment—in which time is an important element—and fired with elevation at the rate of 20 rounds per hour for a few hours?*

The lowest pressure registered on the base of the 12-inch shot was 15·8 tons per square inch, with 115 lbs. W.A.P. (No. 9), the corresponding energy being 8,090 foot-tons. Eight 12-inch discharges with English P. powder gave *less* velocity and striking force, with *greater* expulsive pressure behind the projectiles. The 18th discharge exerted nearly double the pressure on the shot *with less* useful work. The 9th shot had evidently less "oblique movement" than any other 12-inch projectile; and every other shot did far too little work outside the gun, and far too much inside it, absorbing several hundred foot-tons of work at each discharge, to its own detriment and to that of the bore.

As the gun was designed to consume 120 lbs. of powder, the W.A.P. charges of this amount have peculiar interest. The first one, No. 15, justified Colonel Campbell, Sir W. G. Armstrong, and Sir Joseph Whitworth in fixing upon that charge for the gun. Notwithstanding the loss of power incidental to balancing projectiles upon two points, the "oblique movement of the axis" resulting therefrom, was least severe when the bore was smooth. The average pressures registered by 120 lbs. P. behind the 700-lbs. shot, when the 12-inch bore was smooth, without erosion, burrs, enlargements, &c., were only about six tons more on the square inch than those registered by 85 lbs. P. behind the 600-lbs. shot, whilst the pressure yielded by No. 15 was only three tons more.

M.L.R. gun.	Shot.	Powder charge.		Maximum pressure per square inch.			Observed velocity at 50 yards.	Remarks.
		Brand, W.A.P.	Weight.	A. Inner end of bore.	B. Vent.	C. Base of shot.		
	lbs.		lbs.	tons.	tons.	tons.	feet.	
12-in., 25-tons	600	18 May, 1870	85	18·0	16·8	15	1,290	Mean of ten rounds, except base pressure, one round.
12-in., 35-tons	700	18 Oct., 1870	120	24·4	20·1	21·6	1,309	Mean of three first 120-lbs. charges.
„ „	„	„ „	„	**20·0**	**18·4**	**18·0**	**1,312**	**First 120-lbs. discharge, No. 15.**

Taking this 15th (120-lbs.) discharge as the standard of comparison, it will be observed that the enlargement of the bore at the point where the front-stud hammers and of "driving" contact with the rear-studs had already commenced (see last column of Table II); and that the "oblique movements" of the next two shot fired under identical conditions, offered enhanced resistance to their escape, so that they did somewhat less useful work outside the gun, causing a rise of 5·4 tons in the base pressures.

The eccentricity in the velocities as compared with the irregularity in the pressures, rapidly increased as the bore roughened, culminating at the 28th discharge, when 66 tons' pressure was registered at the bottom of the bore, and 53·2 tons at the base of the shot, yielding only 621 foot-tons extra blow.

Thus, in the course of thirteen horizontal discharges, spread over five weeks, maximum pressures are evolved from two identical 120-lbs. W.A.P. charges, of 20 and of 66 tons respectively. The problem of the Surveyor-General of the Ordnance might well assume a different form, for it is not a question here of different amounts or different kinds of powder, of different elevations, or of different chamber temperatures. Every condition is identical. The gun was carefully nursed on both days. It was the third horizontal discharge on each day that we are comparing, and we may assume that the intervals between the discharges were equally large. Yet $3\frac{1}{2}$ times greater pressure is registered on one occasion than on the other. Why is this? Again I ask, has any powder-manufacturer found that carefully-made gunpowder varies in its explosive force to the extent of $3\frac{1}{2}$ times the pressure? Do shells explode with $3\frac{1}{2}$ times their wonted violence without cause? Do torpedoes manifest eccentricities to this extent? Do miners find that identical charges of similar powder, fired under like conditions, explode with $3\frac{1}{2}$ times their usual force? Vary the question as you will,

nowhere but in a Woolwich rifled gun, containing a non-centering shot balanced in unstable equilibrium upon two points, and restricted to a short rifle-bearing of 1 inch in each groove, there, and there only, do similar charges fired under like conditions, produce such anomalous results.

There are, of course, waves in a gun, just as there are waves in the sea; but when the waves of the sea singled out and engulphed a particular ship in the midst of a squadron, the common sense of seamen told them that the fault must have been in the ship and not in the waves. And when gunpowder plays such pranks in a gun, every intelligent gunner knows that it is not the gas-waves but the shot which must be at fault.

Again, we are told that it was "intense wave pressures" and "local "action" which disabled the gun. Now this 66 tons' pressure was registered more than 3½ feet from the spot where the whole of the injuries are concentrated. (Plate I.) And if the shot had centred itself in the bore, even the 53 tons' pressure on its base could not have reached within several inches of the damages; so that it is perfectly clear that it was not the direct action of the maximum powder-pressure which disabled the gun, but the mechanical movements of the shot acted upon by these great pressures,—the two forces, viz., the wriggles of the shot and the combustion of the charge, acting and reacting upon one another.

The Loss of Striking Force.—Though the loss of endurance is a serious matter, the loss of power is hardly less serious, since it compels us to reduce the charges and then to employ a gun of 35 tons' weight to do the work of one of 25 tons, and again to build one of 50 tons' weight, of still less endurance (unless it be confined to reduced charges), to do the proper work of a 35-ton gun, and, possibly, a 70-ton gun to do the work of a 50-ton one. For not only is useful work abstracted from each powder-charge, but we are compelled to employ smaller charges than the bore could usefully burn. Thus, the 35-ton gun could easily burn the 120 lbs. of P. powder, for which it was designed, but, owing to these "oblique movements of the axis of the projectile," and to the resulting accumulation of gases in its rear, the Committee report "*that* "*two rounds of such a charge* (115 lbs. P.) *will not be a dangerous* "*proof*," and the service charges are reduced from 120 lbs. to 110 and 85 lbs. P. The loss of striking force resulting (1) from the non-centering of the axes, and (2) from the reduction of powder charge, can hardly be less than 1,500 foot-tons, *i.e.*, than *from one-fifth to one-sixth that which the gun is capable of yielding.*

Thus whereas, at its own muzzle, the 35-ton gun has now barely force to perforate 12-inch armour and backing at the extreme "biting" angle, its muzzle-blow would suffice, if it had not "decidedly the "lowest velocities,"—and was not obliged to reduce its charge,—to perforate 14-inch armour and backing at the extreme "biting" angle. Two additional inches of armour perforation would thus be gained, whilst prolonging the life of this sickly "infant."

Captain Maitland, R.A., the Deputy-Superintendent of the Royal Gun Factories, stated at the Civil Engineer's Institution, last year, that "the object kept steadily in view by the authorities was to get

"the highest possible velocity out of a gun with the heaviest possible "projectile, or, in other words, to get through the thickest armour-"plate at fighting distance." And the learned Professor of Artillery stated on the same occasion, that "high velocities were most desirable, "as they gave longer ranges, more accurate practice, and greater "striking power than low velocities, and in some circumstances, such "as firing at iron-plated vessels, they were indispensable. High "velocities were fully appreciated in continental services, and by most "eminent ordnance manufacturers or inventors, such as Krupp, "Armstrong, Whitworth, Lancaster, Palliser, Scott, and others." Admiral A. Cooper Key, C.B., F.R.S., when Director of Naval Ordnance, enunciated the axiom that the first essential of a naval gun is endurance, and the second "penetrating power at ranges up to "1,200 yards."

In the face, however, of every artillery authority, and of the fact that perforating force varies as the squares of the velocities, we deliberately employ a rifling of which the official advocates themselves reported that, even when firing the same charges, it "has decidedly the lowest "velocities," and which compels us to diminish the velocity and perforation still more by reducing the powder charges far below those which the several bores could usefully consume; whilst the 7-inch gun thus reported upon, itself stated by a steel engraving of its own, that its projectiles had destroyed its bore, in their attempts to attain even "decidedly the lowest velocities." (See Plate III.)

Pressures in 25-ton Guns.

But do other French or miscalled "Woolwich" rifled guns suffer in this way? Certainly they do; but the mischief increases with the weight of the shot to be projected, inasmuch as the rifle-bearing in each groove is less for a 700-lbs. shot than for a 115-lbs. projectile. Every heavy studded projectile which is fired is so injured in "wabbling" its way out of the gun, that it is obliged to be melted up. Now these heavy projectiles cost a good deal of money; 12-inch ones cost, for example, nearly £5. Are five-pound notes so plentiful that anybody can afford to burn them lightly, or without good cause? Is not this re-melting of recovered projectiles sufficient evidence that unmechanical contrivances have been absorbing work within the bores that ought to have been acting on hostile armour?

What mean those "local enlargements, dents, and even occasionally "cracked tubes," testified to by the Special Committee,* as the result of proving guns with only $1\frac{1}{4}$ times their diminished or miscalled "battering" charges?

The Committee on Explosives tell us† "that, with a 12-inch calibre, "the (25-ton) gun would probably consume 95 lbs. of powder with as "good useful effect per lb. of powder, and with no greater pressure per "square inch than it does 85 lbs. of powder with an 11-inch calibre." Why, then, are the miscalled "battering" charges of this gun 10 lbs.

* "Extracts of Artillery Proceedings," &c., vol. x, Part II, page 81.
† "Report" of 1st April, 1872, p. 3.

below its powers of combustion? Simply because, even with 85-lbs. charges and 600-lbs. shot, the maximum pressures vary from 14·4 to 20·5 tons on the square inch; and with 95 lbs. there is no saying what they might jump to.

Why should 600-lbs. shot in a 12-inch bore yield so much higher pressure than 700-lbs. shot in a similar bore? Does the gunpowder know instinctively that the weight of the gun is less? Does a short 12-inch gun 12 calibres in length, consume its charge better than a longer 12-inch gun of $13\frac{1}{3}$ calibres? Or, is it not capable of easy demonstration, that the mechanical action of the shorter 600-lbs. shot about its rear-studs is more lively than that of the longer shot?*

The loss of endurance in the 25-ton gun is so great, that not one of the class has been subjected to an ordeal anything like what they would have to undergo in a naval bombardment; whilst the loss of velocity and striking force is such that, properly rifled, the 12-inch 25-ton gun would perforate the "Glatton's" turret easily, and penetrate whatever the present 35-ton gun can penetrate.

Pressures in 18-ton Guns.

The influence of length upon the "oblique movements" of the shot was evidenced by the 10-inch gun experiment with similar charges behind projectiles of varying length and weight.† The weights of the projectiles varied from 300 to 1,200 lbs., and it was found that with similar charges of P. the additional weight of shot, after 450 lbs., gave very trifling increase to the powder pressure, whilst the regularity of the pressures and the correspondence of the velocities was much enhanced. The results were still more confirmatory when the more violent quick-burning R.L.G. was used, for the wriggling movements of the short 300-lbs. shot caused higher pressures than those of the longer 600-lbs. shot, using the same (60-lbs.) charges; thus justifying the Official Report‡ that "when *any description of powder is increased* " beyond a certain limit, wave or local pressures are set up which strain " the gun unduly, *without affording an equivalent of useful effect on the* " *projectile.*" Clearly, then, in the judgment of the Committee, the " description of powder" has nothing whatever to do with the erratic relations between the pressures and velocities.

Firing its ordinary 70-lbs. P. and service 400-lbs. shot, the pressures in the 10-inch 18-ton gun show to a slighter extent the operation of similar mechanical forces within; but when the proof charge, $87\frac{1}{2}$ lbs. P., was used, the eccentricity was quite as remarkable as in the 35-ton gun, the pressures rising to 63·4 tons. 29·8 tons per square inch pressure on the base ejected the shot with three feet *more* velocity than it had when driven out by 12 tons per square inch higher expulsive force. Clearly there was an enormous extra force applied to the shot which must have been conveyed by it, through its studs, to the gun, inasmuch as it did not carry this extra force out of the bore.

As might be expected, the quicker burning and more violent R.L.G.

* The mechanical action here referred to is the "oblique movement of the axis," not the rotatory force.

† "Extracts of Artillery Proceedings," vol. x, Part II, page 84.

‡ See "Report of Committee on Explosives," 1st April, 1872, page 7.

powder was even more erratic than the P. For, with the service 60-lbs. R.L.G. charge, the expulsive pressures on the base varied from 22·5 to 33·9 tons, without any adequate increase of velocity. And when the proof 75-lbs. R.L.G. charge was employed, the maximum pressures jumped to 66·8 tons, exceeding any registered in the 35-ton gun, but without the slightest damage to the powder-chamber. Are the guns then uninjured by these irregularities? No. The lands and grooves which are traversed by the projectiles, but are not subjected to these excessive powder-strains, are marked "by local enlargements, dents, and even "occasionally cracked tubes." The position of all these abrasions clearly shows that they must have been made by the projectile, and the only part of the projectile which is supposed to touch the bore is the stud. (Plate II.) Obviously, wherever a stud makes a dent or local enlargement, the process of making it must check the exit, and the projectile must endeavour to revolve on that point, and, doing so, must wriggle with such severity as to still further obstruct its own escape, giving extra time for the more perfect combustion of the charge and causing the gases in the rear to accumulate.

Even when such small (40-lbs.) P. charges were employed that the maximum pressures did not exceed ten tons on the square inch, the expulsive forces were occasionally highest when the velocities were lowest. But for this, the 10-inch gun might consume 87½ lbs. of powder with advantage, striking a blow several hundred foot-tons heavier than at present; in fact, perforating armour which we are now obliged to employ a 25-ton gun to perforate.

Powder charge. 10 in. 400-lbs. shot.			Observed velocity at 50 yards.	Maximum pressure per square inch.				Striking force at 50 yards.	Position of base of shot when maximum powder pressure was registered. Plate II.
Brand.	Weight.	Length of cartridge.		A. Inner end of the bore.	B. 11 ins. from inner end of the bore.	C. 25 ins. from inner end of the bore.	I. 38·3 ins. from inner end of the bore.		
	lbs.	in.	feet.	tons.	tons.	tons.	tons.	foot-tons.	
W.A.P..	70	25	1,413	23·7	21·3	20·9	19·9	5,539	Halfway between C and I.
"	"	"	1,431	22·5	22·6	22·7	12·0	5,675	
W.A.P..	87½	29	1,527	25·0	29·8	30·0	29·8	6,466	Nearly at I.
"	"	"	1,524	63·4	41·6	37·0	41·9	6,443	
R.L.G...	60	25	1,317	57·8	29·4	31·1	18·2	4,807	At C.
"	"	"	1,325	36·5	27·0	22·5	16·5	4,868	
R.L.G...	75	28	1,388	41·8	22·8	21·3	16·6	5,344	Three inches outside C.
"	"	"	1,426	66·8	28·0	35·0	28·1	5,635	
W.A.P..	40	—	996	9·0	8·7	9·9	7·8	2,750	At C.
"	"	—	1,006	8·8	9·2	8·8	8·5	2,807	
W.A.P..	70	25	1,345	19·3	19·0	19·0	16·5	5,021	Halfway between C and I.
"	"	"	1,360	20·1	18·8	17·1	16·3	5,128	

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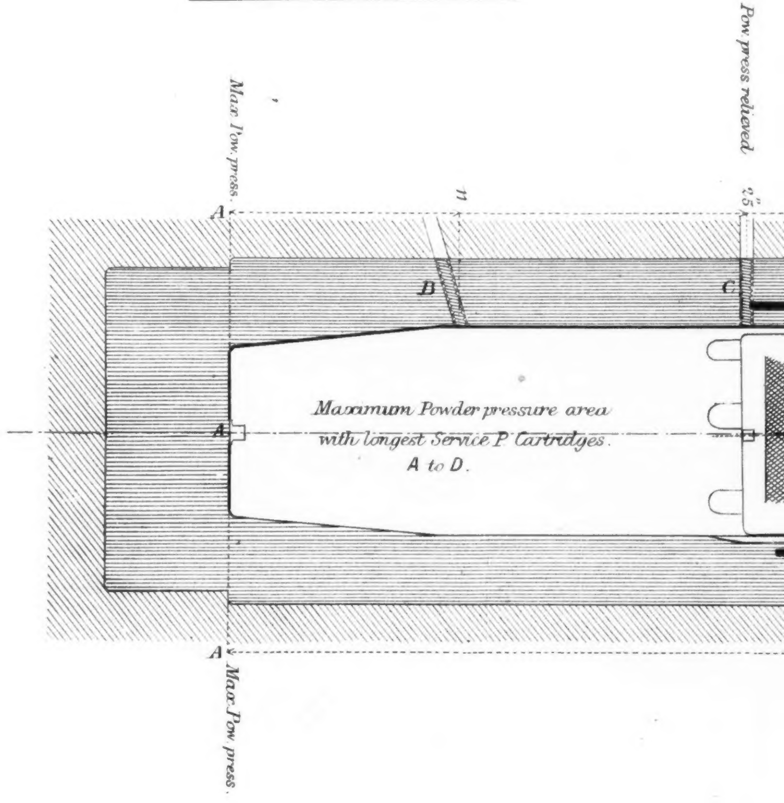
Journal R. U. S. Institution
Vol. 17

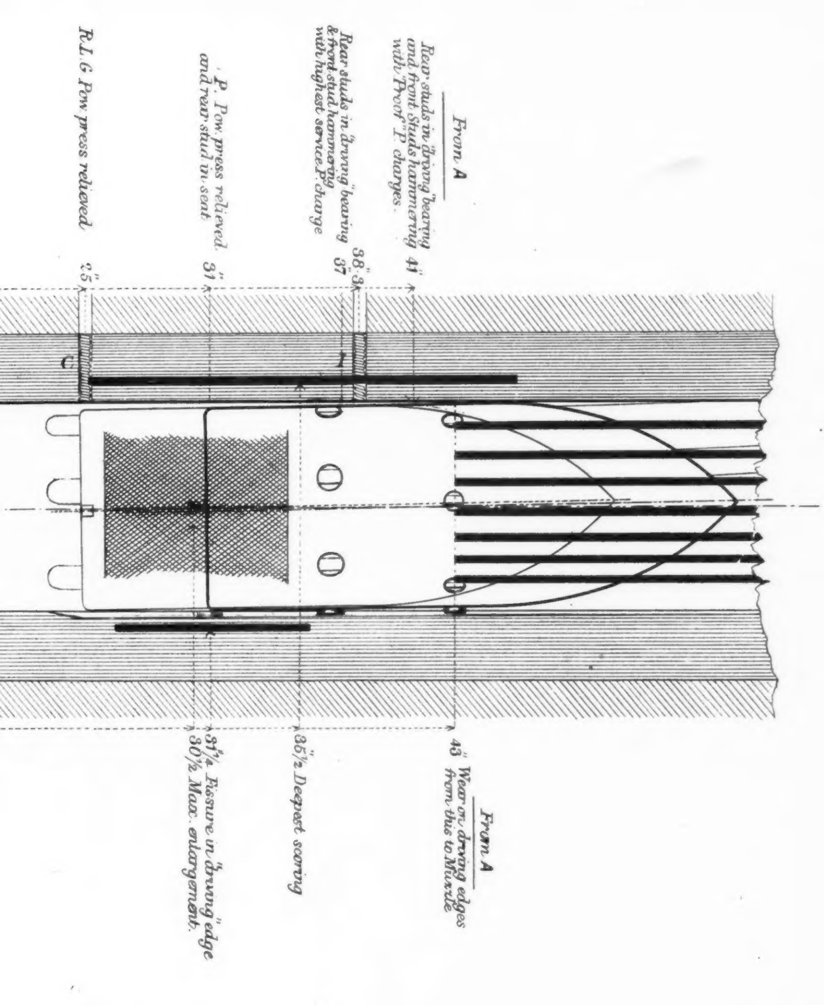
Interior of

10 INCH 18 TON M. L. R. EXPERIMENTAL GUN No 375.

3rd January 1872.

After 241 discharges.- Rear Stud coming into bearing




From A
Rear studs in "driving" bearing and front studs hammering with "Proof" P. charges. 41"
Rear studs in "driving" bearing & front stud hammering with highest service P. charge 38"·3 37
P. Pow. press relieved and rear stud in seat 31"
R.L.G. Pow. press relieved 25"
C
From A
43" Wear on driving edges from this to Muzzle
35½" Deepest scoring
31½ Fissure in "driving" edge
30½ Max. enlargement.

J. Jobbins

The state of the bore (Plate II) of this 10-inch 18-ton gun (Expl. No. 375), after the pressures were registered, shows that the studs had made and had to pass over a maximum enlargement of upwards of one-tenth of an inch in front of their seat, roughness of the bore, the deepest furrows of which were about the same spot, a fissure on the driving edge of the left groove, and wear on the driving edges of all the grooves: and this though only 241 rounds had been fired at wide intervals of time and horizontally, at the date of the examination, viz., 3rd January, 1872. Though these marks and injuries were not in themselves of a vital character, they would greatly intensify the force of the "oblique move-"ments of the axis" of the 400-lbs. projectiles about their studs, and enhance the eccentricity of the maximum pressures with identical powder charges.

In Plate II, the 400-lbs. shot is shown in its seat with the longest service P cartridge, and again, in the corresponding position with the rear-studs coming into "driving" bearing. With the shorter cartridges, the rear-studs would be nearer the inner end of the bore. As illustrated, the seat of the rear-studs correspond with the centre of the maximum enlargement.

State of the 10-inch bore. Expl. No. 375, 3rd. January, 1872. (See Plate II.)		Distance from inner end of bore.		Vertical position in the bore.
		Extremes.	Centre.	
Fissure in "driving" edge of groove		26½ to 36 in.	31¼ in.	left groove
Wear on "driving" edges of grooves		43 to 145 „	94 „	all grooves
Maximum roughness, or deep scoring		25 to 46 „	35½ „	up
Maximum enlargement about ·1 inch		26 to 35 „	30½ „	round
Rear-stud in seat	According to length of cartridge.	26 to 30 in.	28 in.	down
Rear-stud coming into "driving" bearing		32 to 36 „	34 „	round
Front stud hammering		32 to 36 „	34 „	up
Maximum P. powder pressure area		27 to 31 „	29 „	—

Colonel Campbell testified to the Ordnance Council, 4th May, 1870, that the Woolwich "system has the great disadvantage of local "scoring." And Mr. Bashey Britten told the Institution of Civil Engineers, that "those who had seen the inside of a Woolwich gun which "had done much work, would know that for from 12 to 24 inches from "the cartridge, the bore sometimes became as rough as the bark of a "moderate-sized elm tree; and it was up such a surface that the hard "studs had to slide. If the rifling acted uniformly, the pressures on "the gun would vary constantly with the *vis viva* imparted to the "shot; but in nearly all cases when extraordinary pressures were "detected, less *vis viva*, instead of more, was acquired by the projectiles. " * * * * The liability of the studs to get jammed "was necessarily increased under such circumstances, and then they "could only be released by the pressure gathering behind them. The

"velocity of the shot might therefore be expected to be less, while the "strain was greater."

Powder Pressures in the 11-*inch* 18-*ton Gun, Expl. No.* 375.—The injuries to the 10-inch bore (No. 375) were got rid of by boring it out to 11 inches calibre; and certain comparative experiments were made with 11-inch 400-lbs. projectiles. The larger the bore, the more perfect and regular the combustion of equal weights of powder, and the less violent the action upon the studs. Hence larger charges can be employed in larger bores with less "wabbling," and therefore lower and more regular pressures. Thus the 400-lbs. shot gave, with 85 lbs. P. charge, in an 11-inch bore, 8½ per cent. *less* pressure, and 16·7 per cent. *more* work than when propelled by 70 lbs. P. powder in a 10-inch bore. The initial energy per inch of the shot's circumference being with the 11-inch shot 172·2, and with the 10-inch shot 161·8 foot-tons, or a total muzzle-blow of 5,855, and 5,016 foot-tons respectively; and the corresponding mean maximum pressures at the inner end of the bore, 17·8 and 19·4 tons per square inch.

Though the 11-inch bore, being fresh from the factory, had a polished surface, free from dents, abrasions, roughnesses, and wear on the edges of the grooves, and was, therefore, most favourable to regularity of action; still the "oblique movements of the axis of the projectile" are traceable in the milder pressures registered with the 11-inch 400-lbs. shot, *e.g.*, 14·9 tons per square inch expulsive force on the base of the shot yielded 5,800 foot-tons blow, but nearly 2 tons per square inch *more* pressure gave, under apparently identical conditions, 43 foot-tons *less* blow, and nearly 1 ton *more* pressure yielded 157 foot-tons *lighter* blow.

P. Powder charge. 11-inch 400-lbs. shot.	Observed velocity.	Pressure by Crusher-gauge per square inch.				Striking force.	Position of base of shot when maximum pressure was registered.
		A. Inner end of bore.	B. 11 ins. from inner end of bore.	C. 25 ins. from inner end of bore.	I. 38·3 ins. from inner end of bore.		
	feet.	tons.	tons.	tons.	tons.	foot-tons.	
85 lbs., lot 863 ...	1,484	19·3	18·3	19·4	14·0	6,109	About halfway between C and I.
" " ...	1,465	18·1	17·0	18·0	12·6	5,952	
" " ...	1,466	20·7	16·0	15·6	14·0	5,961	
85 lbs., lot 1,404 ..	1,441	17·2	16·3	16·8	12·5	5,757	
" " ..	1,433	16·4	16·1	13·3	13·1	5,692	
" " ..	1,427	15·6	14·9	15·6	12·3	5,643	
" " ..	1,446	16·5	15·3	14·9	12·5	5,800	

NOTE.—See Mr. Bashley Britten's very able and instructive reply to the discussion at the Institution of Civil Engineers, appended to his paper on "The Construction of Heavy Artillery."

Powder-Pressures in other Heavy Guns.

As every heavy projectile is damaged in escaping out of the bore, each shot must divert mechanical force to that object, and the necessary result is, that a great many guns have been more or less injured in slow firing with diminished charges of powder at low elevations during the past eight years. The Ordnance Inspector's Reports on these numerous injuries must be very bulky and dry literature. Yet, in the interests of the public service, I volunteered, at my own cost and labour, critically to examine the whole of those records, with the view of tabulating the positions of the several damages, in the hope of thus showing in each case how, when, and where the mechanical forces were misapplied, with the corresponding loss of endurance and of striking force, and I requested the oversight and approval of the Director of Artillery to such extracts as I might be permitted to make.

This laborious undertaking, which could be no possible personal benefit to myself, I would have performed gratuitously, free of cost to the State, in the hope of elucidating the mechanical forces in operation in each case, and, by studying the mechanical disease, arriving at such a mechanical remedy as would contribute to the efficiency and credit of the Service and to the safety of the country. But access to these official records was denied me. Why? Would they reveal anything unknown to the profession?

However, where so many guns are disabled and others injured every year, facts will ooze out; and I have examined the official records of a considerable number of marked and damaged bores. Moreover, I have studied, for sixteen months, the connection between the marks upon the bore and upon the projectiles, and variations in the Practice Tables and Powder-Pressures. I find that, in general, the principal marks in the bores are in one of two positions, viz., either a few inches in advance of the seat of the rear-studs, where they come into "driving" bearing, and where the front-stud hammers; or near the muzzle where the front-studs are intended to do their share of the work. There is also, of course, the roughness or erosion which is greatly intensified by the stud-system, as Colonel Campbell pointed out to the War Office Council on the 35-ton gun, saying—"The system has the great disadvantage of local scoring." A worn gun usually gives out less useful work on the target, combined with higher pressures in the chamber.

These things are so well known, that many shot fired from the 8-inch and other experimental guns have no studs at all. These particular guns have, therefore, shown great apparent endurance; but powder-pressures registered when the shot are unrifled afford no criterion whatever as to the pressures arising from "the oblique movements of the axis of the projectile" about its studs. The unstudded shot do not centre in the bore, and their pressures would, in consequence of the body of the shot being below the axis of the piece, and being in contact with the bore, vary according to the presence or absence of fouling matter in the gun. These pressures ought, therefore, to be higher but somewhat less erratic than when studs are employed.

Incautious students are apt to be betrayed into erroneous conclusions both as to endurance and as to pressures in these experimental guns, from ignorance of the above fact, which is not always stated in the published tables.

Mr. Bashley Britten pointed out at the Institution of Civil Engineers, last year, that "there was no reason why gunpowder should not act as "uniformly in rifled guns as in smooth bores, unless the rifling and the "projectiles were designed on unscientific principles. A rifle shot "had to perform in a gun the functions of a screw; and the power to "turn a screw working properly was definite and constant. If it "could not follow the thread it worked in, but overrode the sides, it "became locked. * * * The instant a shot was checked "by any obstacle in its course through the bore, the *vis viva* of the "column of gas moving in one direction was necessarily converted into "pressure on the gun. The 'grip at the muzzle' in the Armstrong "shunt gun was found to produce sufficient check to cause concussion-"fuzes, having movable strikers, to explode at the muzzle. The first "four 600-pounders were shunt guns, each costing £4,000, and weighing "23 tons. In the official Text Book it is stated 'of these four, by "'March, 1867, two were rendered unserviceable during experimental "'practice at Shoeburyness, by splitting their A-tubes and some of "'the coils, and another by splitting its outer coil.' A 9-inch shunt "gun burst into 42 pieces on one occasion, at the 402nd round. These "failures were officially attributed to the shunt rifling." Similarly a 9-inch 12½-ton "Woolwich" gun exploded into many pieces at the first "proof"-round in 1868; and a 7-inch 68-pounder "Woolwich" rifled gun exploded into 76 pieces, scattered over an area of 580 yards by 150 yards, in 1870, at the 165th round.

All "intense wave pressures," say some! But why at the 165th round? Oh! the powder was all wrong. But the committee say that "any description of powder" used in large charges is liable to these erratic and unaccountable "wave pressures." Is "any description of" *gun* subject to such irregular "wave pressures," except a Woolwich rifled one? 30-lbs. charges were used in the exploded 7-inch 68-pounder; do 35-lbs. charges in 12-inch shell play such extraordinary pranks?

Studs in Uniform Spirals.—Where uniform spirals are adopted in connection with short-bearing studs, balancing the shot nearly under the centre of gravity, the tendency to "oblique movements of the axis "of the projectile" about its studs is equally present; whilst the absence of that ever-increasing resistance peculiar to the ever-increasing spiral, is evidenced by the tendency of the studs to hammer intermittently against the uniform grooves, and thus to mark themselves in steps, instead of in the wedge form peculiar to the accelerating twist. The injuries thus inflicted upon the uniform-twist bores are necessarily either at or in advance of the seat of the short-bearing studs, showing that the guns are not destroyed by the powder but by the projectile. True, the uniform spiral gives the studded shot a greater velocity, in consequence of the absence of that ever-increasing resistance which reaches its maximum in the ever-changing angle of spiral when the

shot is at its highest speed. But the short-bearing stud, even with an uniform twist, gives less velocity and perforation than the long-bearing centering shot, proving that work is taken up in the bore to the destruction of both projectile and gun. The position of the injuries in such uniform-spiral stud guns verifies the writings in the steel bores of increasing-spiral guns. As samples of the injuries inflicted by studded projectiles after 500 rounds from each gun, take the following 7-inch uniform-spiral guns:—

	Expl. No. 200, 7-inch gun, May, 1872.			Expl. No. 198, 7-inch gun, May, 1872.			Expl. No. 299, 7-inch gun, May, 1872.			Expl. No. 199, 7-inch gun, May, 1872.		
	Distance from inner end of bore.		Vertical position in bore.	Distance from inner end of bore.		Vertical position in bore.	Distance from inner end of bore.		Vertical position in bore.	Distance from inner end of bore.		Vertical position in bore.
	Extremes.	Centre.		Extremes.	Centre.		Extremes.	Centre.		Extremes.	Centre.	
	Inches.	Inches.		Inches.	Inches.		Inches.	Inches.		Inches.	Inches.	
Much wear on "driving" edge of groove.	23½ to 41	32¼	Down	13¼ to 19	16¼	Down	12 to 22	17	Down	12½ to 20	16¼	Down
Slight wear on "driving" edge of two other grooves	14¼ to 21	17¾	Up	—	—	—	—	—	—	—	—	—
Bore grazed by projectiles	39 to 48	43½	Up	—	—	—	34 to 47	40½	Up	39 to 46	42½	Up
Ditto ditto ..	20 to 24½	22¼	Left	16½ to 19	17¾	Left	35 to 44	39½	Up	12¾ to 14¼	13½	Up
Indentation..........	—	14¾	Down	—	—	—	—	—	—	—	—	—
Maximum roughness, or deep scoring	17 to 35	26	Up*	11½ to 29⅛	20½	Up	10½ to 24	17¼	Up	10 to 25	17½	Up
Ditto ditto ..	16 to 31	23½	Down	10 to 22⅛	16½	Up	13½ to 24½	19	Down	14½ to 21	17¾	Down
Maximum enlargement	(·125 in.)	22	Round	(·029 in.)	16	Round	(·039 in.)	16	Round	(·039 in.)	16	Round
Gun re-vented	Five times.						Twice.			Twice.		
According to length of cartridge:												
Rear-stud in seat	11 to 14	12½	Down	11 to 14	12½	Down	11 to 14	12½	Down	11 to 14	12½	Down
Rear-stud coming into "driving" bearing	13 to 16	14½	Round	13 to 16	14½	Round	13 to 16	14½	Round	13 to 16	14½	Round
Front stud hammering	15½ to 18½	17	Up	15½ to 18½	17	Up	15½ to 18½	17	Up	15½ to 18½	17	Up
Maximum powder pressure area	15 to 18	16½	(P.)	9¼ to 12¼	10¾	(R.L.G.)	9¼ to 12¼	10¾	(R.L.G.)	9¼ to 12¼	10¾	(R.L.G.)

* No. 200 was very much scored and enlarged. The scoring was so extensive that the gun had to be subsequently turned over, so that the hammering and scoring might change places.

Velocities in Uniform-Spiral 12-pounders.—The French Government have been trying the uniform-spiral Woolwich system against the long radial-bearing rib of Vavasseur, which is similar in its mechanical action to Scott's centering system. Two, otherwise identical 12-pounders, rifled on these two methods, were tried at Bourges last year, when the "Woolwich" stud projectile had, as usual, "decidedly the lowest "velocities," escaping with 16 feet less initial speed, and attaining 338 yards less range, with less accuracy, when the long-bearing one reached 3,760 yards; thus showing—1. That useful work had been absorbed in the short-bearing gun; and 2. That further useful work was abstracted by imperfect rotation in the air.

The Woolwich-made 9-pounder presented to the French Government is somewhat heavier than the above guns, and throws a 9-lbs. projectile with $1\frac{3}{4}$ lbs. R.L.G., which is a proportionately heavier charge. The turned shot supplied with this gun from the Royal Arsenal have been fired at Bourges, and are now being rifled by Messrs. Vavasseur with long-bearings for the French Government, to be fired from the Vavasseur 12-pounder, as a conclusive comparative experiment.

M. J. Vavasseur has permitted me to verify the following figures by comparing them with the original letter of the President of the French Commission on Artillery at Bourges:—

Données relatives aux Canons Vavasseur et de Woolwich Expérimentés a Bourges en 1872.

Provenance des Canons.	Canon.							Projectile.				Charge.			Vitesse initiale.	
	Poids.	Ame de la pièce		Système.	Rayures.							Poids.			Par seconde.	
	En kilogrammes.	Longueur.	Diamètre.		Profondeur.	Largeur.	Pas en calibre.	Diamètre.	Longueur.	Poids.	Surface extérieure.	Livres Anglaises.	Kilogrammes.	Sorte de poudre.	Pieds Anglais.	Mètres.
		m.	mm.		mm.	mm.		mm.	mm.	k.						
Vavasseur à rayures, No. 730	413	1 ·612	76 ·2	Woolwich— 3 rayures ..	2 ·79	20 ·32	25	74 ·68	241	5 ·443	brute de fusion.	2	0 ·907	R.L.G.	1255	382 ·8
Vavasseur à côtes saillantes, No. 743	413	1 ·612	76 ·2	Vavasseur— 3 côtes	4 ·45	10 ·16	25	74 ·68	241	5 ·443	brute.	2	0 ·907	R.L.G.	1271	390 ·4

Résultats des Expériences comparatives faites à Bourges des Canons Vavasseur et de Woolwich.

Constructeurs des Canons.	Nombre de Coups.	Portée moyenne. P.	Ecart longitudinal moyen. E.	Dérivation moyenne. Δ.	Ecart latéral moyen. D.	Coefficient de justesse. En direction. $R = \frac{D}{P}$	Coefficient de justesse. En portée. $G = \frac{E}{P}$	Dimensions du rectangle comprenant tous les coups. Longueur.	Dimensions du rectangle comprenant tous les coups. Largeur.	Observations.
Angle de tir 12°. Vent faible.										
Vavasseur à rayures, No. 730	12	3421·6	115.72	23.62 Dr.	17.89	0.0052	0.0338	512	37.2	
Id. à côtes saillantes, No. 743 .. .. Couchon conique en zinc.	12	3760	88.44	13.57 „	10.84	0.0028	0.0235	365	65.0	
Mécanisme percutant.	12	3754	44.53	12.89 „	12·518	0.0033	0.0118	159	34.9	
Angle de tir 14°. Vent faible.										
Vavasseur à rayures, No. 730	14	3767.1	84.68	15.22 Dr.	5.39	0.0014	0.022	508	31.4	Un obus brisé dans l'âme.
Id. à côtes saillantes, No. 743	15	4088.6	47.95	46.52 „	5.71	0.0014	0.012	189	27.8	
Angle de tir 16°. Vent faible.										
Vavasseur à rayures, No. 730	14	4125.4	123.1	1.17 Dr.	6.19	0.0015	0.030	434	27.7	Un obus brisé dans l'âme.
Id. à côtes saillantes, No. 743	15	4420.9	101.5	43.43 „	5.45	0.0012	0.023	373	23.7	

NOTE.—Les expériences pour chaque angle de tir sont faites le même jour et toutes les circonstances extérieures sont identiques pour chaque canon.

THE ORIGINAL 7-INCH "WOOLWICH" GUN.

Nothing has occurred to the 35-ton gun that might not have been predicated from the performances of the original 7-inch "Woolwich" gun in 1865. It had an increasing spiral, and a study of its Practice Tables, in connection with the Ordnance Inspector's Report, shows that:—

1. 70 per cent. of the recovered shell were found injured.

2. The struggles of the projectiles to escape from the ever-changing angle of spiral, destroyed the bore in 567 discharges.

3. So much force was absorbed through the studs in the destruction of the bore and projectiles, that the increasingly-resisted shot had "decidedly the lowest velocities," striking 220 foot-tons less muzzle blow than the competitive oval-bore, and 133 foot-tons less than the competitive long-bearing iron-ribbed shot.

4. The studded shot had a higher trajectory within 1,500 yards (the fighting distance), and to drive it so far, with the same elevation, took one-fourth (5 lbs.) greater weight of powder than did its competitive long-bearing iron-ribbed shot.

5. The studded projectiles were slightly less accurate than the iron radial-bearing ones at Admiral Key's fighting range.

On the other hand, the iron radial-bearing projectiles were uninjured, and their lands and grooves were left so perfect that this 7-inch gun was bored up to 8·03 inch calibre to throw shot of 180 lbs. weight instead of the 110 lbs. ones for which it was designed; thus showing a direct relation between endurance and useful work, and that, under otherwise identical conditions, "decidedly the lowest velocities" is the natural result of decidedly the worst endurance.

The powder-pressures were not registered in the original 7-inch Woolwich gun; but the Ordnance Inspector's Report shows that the position of the damages to the grooves and lands corresponded very nearly with the position of those in the 35-ton gun. (Plates I, III.) It seems, then, not unlikely that similar irregularities occurred in the powder-chamber.

The maximum powder pressure area in the original Woolwich 7-inch gun (using R.L.G.), extended from 9 to 18 inches from the bottom of the bore according to the cartridge in use. (Plate III.) The "driving" stud was sometimes in front and sometimes in rear. The elongated projectiles varied from $11\frac{1}{2}$ to 13·88 inches in length, and from 94 to 110 lbs. in weight, and the charges from 12 to 25 lbs. R.L.G. Striking a mean between these quantities, it will be seen that the principal destructive agencies operated very nearly as in the 35-ton gun. The vital cracks in both guns correspond with the spot where the front-stud hammers. The maximum enlargements, the abrasions, &c., in both guns agree as usual with the point of "driving" contact of the driving studs. No marks are recorded outside or inside these points, excepting certain chamber defects in the original Woolwich gun, the result of malformations subsequently remedied, and "the disadvantage of local "scoring." This tender relationship between the first, and, I hope,

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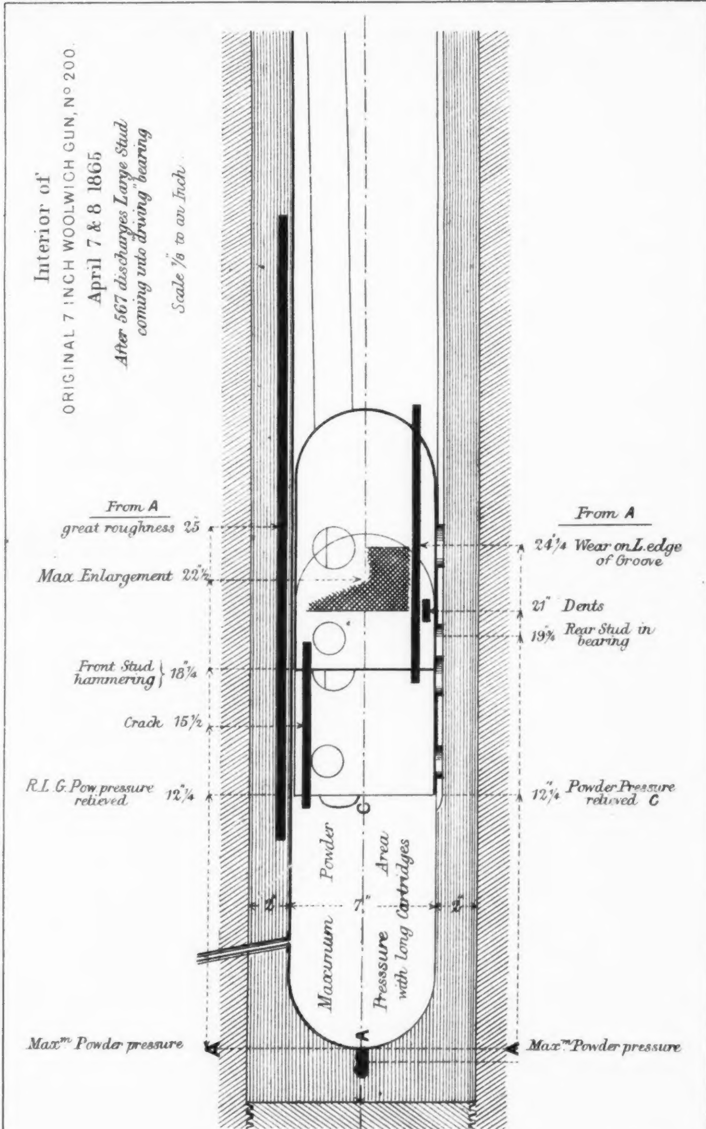
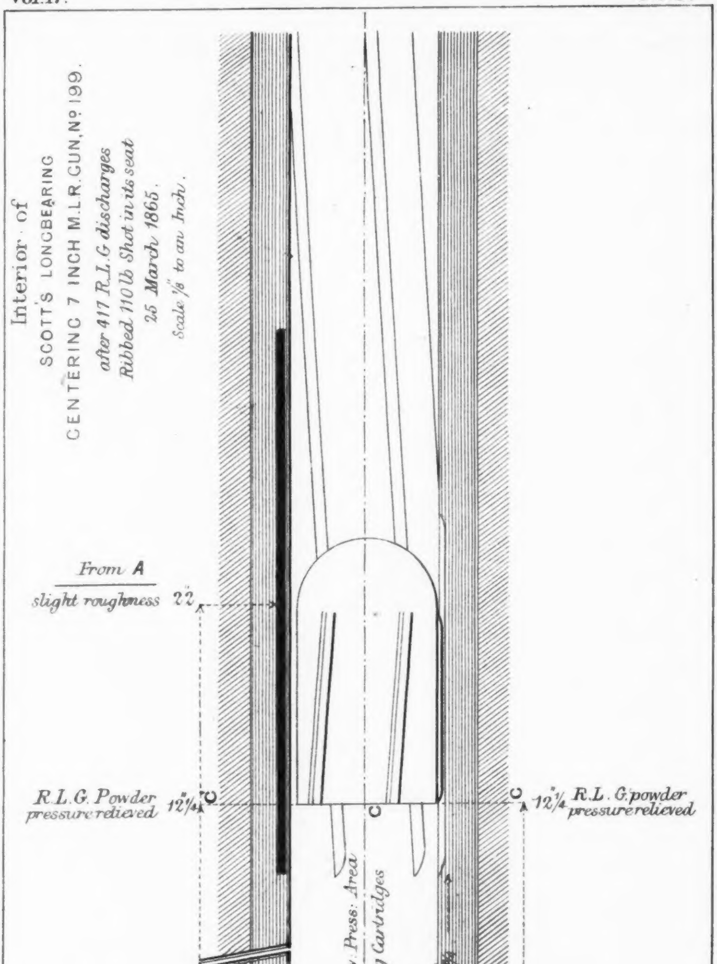
Pl III.



J. Jobbins


Interior of
SCOTT'S LONGBEARING
CENTERING 7 INCH M.L.R. GUN, No. 199.
after 417 R.L.G discharges
Ribbed 110 lb Shot in its seat
25 March 1865.
Scale 1/8" to an Inch.
From A
slight roughness 22"
R.L.G. Powder pressure relieved 12 1/4"
12 1/4" R.L.G. powder pressure relieved
Max: Pow: Press: Area with long Cartridges
Maxm. powder pressure
Maxm. powder pressure
8 3/4
A
C

J. Jobbins

the last of the miscalled Woolwich rifled guns—the venerable parent and delicate infant—ought not to pass unnoticed.

Plate III shows the original 7-inch Woolwich gun after its destruction, with the shot in its seat, and with the rear-stud coming into "driving" bearing, when long cartridges were employed. With shorter cartridges the positions of the shot would be nearer the powder-chamber.

Contrasting Plate III with Plate IV, which shows the competitive Scott long-bearing centering 7-inch gun after the last shot, it will be observed that, in the Scott gun, "*there is no apparent expansion* "*of the bore*," no cracks, no dents, and no wear on the edges of the grooves; whilst the roughness or erosion from the escaping gases is stated by the Ordnance Inspector to have been "slight." The chamber defects in both guns were the result of the hemispherical form of the inner end of the bore, and was common to all four competitive guns. One of the other guns had its chamber squared at the end, after 40 discharges, and the eating way in the axis was entirely stopped. The hole at the axis of the chamber, shown in Plate IV, was subsequently plugged up in Scott's gun, and the barrel bored up to 8·03 inch.

See Plates III and IV.		Original Woolwich 7-inch gun, (No. 200), 7th and 8th April, 1865.			Scott's long-bearing centering 7-inch gun, (No. 199), 25th March, 1865.
		Distance from inner end of bore.		Vertical position in bore.	Position in bore.
		Extremes.	Centre.		
		Inches.	Inches.		
Longitudinal crack		11¾ to 19½	15½	Up	None
Dents in lands and grooves		20¾ to 21½	22¼	Down	None
Wear on *loading* edge of groove		17½ to 31	24½	Down	None
Roughness or deep scoring		10 to 40	25	Up	9 in. to 35 in. from A. (slight)
Maximum enlargement, ·049 to ·042 in.		21 to 24	22½	Round	"*There is no apparent expansion in the bore*"
Slight fissures at vent		—	—	Up	Up
Defect from malformation of chamber		—	—	Axis	Axis, and 1¼ in. from A.
Base of shot in its seat	According to length of cartridge.	9 to 18	—	—	9 to 18 in. from A.
Front stud hammering	According to length of cartridge.	—	18¼	Up	Uniform spiral and long-bearing centres in the bore at starting.
Rear-stud coming into bearing	According to length of cartridge.	—	19¾	Round	Uniform spiral and long-bearing centres in the bore at starting.
Maximum powder pressure area	According to length of cartridge.	0 to 18	—	—	0 to 18 in.

Conclusion.—I have patiently examined, seriatim, every pressure registered in the first 35-ton gun, and I have found that every variation of pressure, where similar charges were ignited under identical conditions, is traceable to the unmechanical method of balancing the shot on two points nearly under its centre of gravity, limiting the rifle-bearing to one inch in each groove, and not centering the projectile in the bore, an absurd contrivance which Mr. Charles Merrifield, F.R.S., the distinguished Principal of the School of Naval Architecture, recently described to the British Association, adding that "the consent "of all mechanicians and engineers with whom he had ever conversed "was absolutely unanimous in the condemnation of the Woolwich "system of rifling, and that he had never heard any serious defence of "it."

During the last sixteen months, I have myself consulted eminent mechanical engineers, manufacturers of guns, of powder, and of projectiles, scientific artillerists, and mathematical professors on every mechanical detail as it arose, communicating alike with those who are committed to this as well as to other systems. These gentlemen have instructed and aided me much, opening to me freely their rich stores of knowledge and experience; some have corrected my erroneous impressions, and to all I owe grateful thanks. But amongst all these experts, I did not come across a single unqualified supporter of the present system of rifling. Certain able and distinguished soldiers had opinions in favour of "the increasing spiral" on which the whole of these evils rest. But when I privately and publicly importuned them for a single reliable fact in support of "the increasing spiral," they had not the shadow of a fact to allege,—nothing but "the baseless fabric of a "vision." Some imaginative individual had made a guess that the maximum pressure in the powder-chamber and the destruction to the gun, would be materially lessened if an increasing spiral were employed, and some dabbler in mathematics conclusively proved that if x and y were cleverly manipulated, powder and mechanical laws must follow wherever those two unknown quantities are directed. But not a single experiment was made to test the correctness of this guess.

Eight years have been spent in trying to make the laws of nature conform to this arbitrary guess. All the talent of Woolwich Arsenal has been concentrated on the problem. Every nature of gun produced has had a different form of increasing spiral. Hundreds of thousands of pounds have been squandered on varieties of projectiles,* each variety devised to meet these impossible conditions. Gunpowder manufacturers have exhausted ingenuity to the same purpose. And what is the result? Simply that an "increasing spiral" causes oscillations of pressure from 20 to 66 tons on the square inch under identical conditions, both in an 18-ton and in a 35-ton gun; and that it has destroyed the latter in 38 horizontal discharges after most careful nursing. Is this the result that the increasing spiral was intended to produce?

* Up to last July, 770,282 projectiles had been studded. At the estimated cost of £77 per thousand, the expenditure on *studding* alone was £59,311. Many thousands of these projectiles have been destroyed, either in store or after having been fired.

At least six heavy guns, rifled with increasing spirals, have been disabled during the past year. Yet 1872 was a year of profound peace. Not a single gun was subjected, during that year, to anything in any way approaching to the ordinary conditions of a naval action. The Practice Tables of the late 35-ton gun show that pressures rise as bores get roughened by repeated discharges. If 32 discharges each, scattered over the whole year, have disabled six heavy guns in 1872, will these guessers and calculators tell us how many hours of elevated fire a worn 35-ton gun would endure at the rate of 20 rounds per hour?

Ships of war are but floating gun-carriages. The most recent ones cost about £100,000 per gun. If these weapons won't endure an ordinary naval action, is it worth while building floating carriages for them? All the intelligence of the Navy protests against being sent to do battle against "foemen worthy of their steel," with weapons that yield the minimum of perforating power, and won't even withstand combats against canvas targets.

If our guns are no longer to have "decidedly the lowest velocities," and decidedly the least perforation; if they are to employ the largest powder-charges which their several bores will burn; if they are to yield an endurance proportionate to their weight and admirable build; and if the powder-pressures are to follow regularly the apparent conditions of the powder-charges employed, every well-informed mechanician believes that we must:—

1. Give the shot the longest possible rifle-bearing in each groove.
2. Adopt cast-iron radial bearings which won't shear or wedge, and will strengthen the projectile.
3. Centre the axes of the shot and the bore during exit, on that plan which gives the greatest windage for loading foul guns.
4. Proportion the twist to the length of the projectile, rather than the converse.

This done, we shall hear no more of unaccountable "wave pressures;" of melting up all recovered projectiles; of Ordnance Inspectors to report, after every 50 discharges, upon injured bores and disabled guns; and I shall be able to return into private life, conscious that I have not dishonoured the Naval Profession by forgetting that, at whatever personal hazard, "England expects that every man shall do his duty."

The CHAIRMAN: Before I convey the thanks of this meeting to Commander Dawson and express to him the satisfaction we have had in hearing such an elaborate paper, and our sense of the enormous amount of research which it must have cost him to prepare that paper for your notice, perhaps some gentleman would like to offer some remarks upon this subject.

Admiral HALSTED: I fully agree with the main points of Commander Dawson's paper. I merely want to say this: Commander Dawson says he has consulted in every direction; but it is very curious that he has omitted to mention one of the most eminent practical mechanicians existing in the world—I mean Sir Joseph Whitworth. Is he already dead and buried? This very question of self-centering rifled projectiles is the original deduction of Sir Joseph Whitworth, obtained from his small-arms shooting gallery of 1857, out of which experience, step by step, have grown the identical rifling of his two 7-inch and two 9-inch guns which we now possess. Then the question of shells has not been touched. Sir Joseph Whitworth is again the only person who can produce a steel armour-shell of five calibres, containing, as Commander Dawson told us, in Sir Joseph's own proposal for his 12-inch rifle, 58 lbs.

of bursting powder, and being upwards of 1,200 lbs. in weight, the same weight as in the proposed Woolwich 45-ton gun. Let me mention this subject again with direct reference to the two 9-inch Whitworth guns which we have now got. What, I ask, is the normal bursting charge of their $3\frac{1}{2}$ calibres armour-shells? It is 15 lbs., and here we have the 35-ton Woolwich gun only capable of giving us about $8\frac{1}{2}$ lbs. But, then, what again is the bursting charge of Sir Joseph Whitworth's 5-calibre 9-inch armour-shell of the same gun? It is 25 lbs. Now, of two 2-turret ships with equal thickness of armour-plating: put two 35-ton guns into the turrets of the one ship, such as are those of the "Devastation" at this moment, and let those guns attack the couple of turrets in the other 2-turret ship armed with Whitworth's 9-inch guns of only 15 tons weight. Let there be equal penetration upon both sides, and who can doubt what must be the result of exchanging shot for shot between an armour-shell carrying a bursting charge of 25 lbs., and another armour-shell carrying a bursting charge of only $8\frac{1}{2}$ lbs.? How long is this going to last? Shell fire is the question of questions with regard to armour-plate artillery. It is not cold shot that we want, but shells. You may go on fighting with cold shot between well-designed ironclads of iron as long as you please. I will defy all the cold shot that shall be produced, say on the French side on the one part, and all that we can produce at Woolwich on the other, to make a hole some 10 or 15 feet under the water line 5 feet long and 4 feet wide, as in the recent case of the "Northumberland," and even when that shall have been done, you only get a couple of water-tight side compartments filled with water, and the ship sails away from Madeira to Gibraltar almost as if she had received a mere flea-bite. And when she gets to Gibraltar she does not go into a dock, but is only careened sufficiently to get a coffer dam over her side, and in less than a week the whole injury is repaired. That is the present state of our well-designed ironclads of iron; they are practically unsinkable by any cold shot you can fire at them. What cold shot could be fired equal in effect to the prow of the "Hercules?" What we want, if we are really to destroy each other in ironclad war, is not cold shot, but the most destructive shell, and you must have a gun able to deliver it; and if you can get guns capable of delivering 5-calibre armour-shells they will have the advantage over those which are only capable of delivering with safety 3-calibre shells. As I say, if only on this all-important question of "shell-fire," this Woolwich system ought never to have been adopted.

Captain Jasper Selwyn, R.N.: I wish to draw attention to the fact that hitherto we have not exactly discussed the paper. The question is not so much what is the best gun—we shall get at that by and by, but how to use best and not misuse the guns we have. I so thoroughly go with Commander Dawson in most of his paper, that I shall only note one point of difference in the explanation of the way in which an elastic gas acts on the base of a shot. It is not quite sufficient to consider that the gas will not pass as well underneath the shot as above, though it is perfectly and absolutely true that while the shot reposes on the bottom of the bore, as it must necessarily do with this system, there is a greater space above the shot than below, and therefore a greater rush of gas through the upper part than below, and that that will produce the tilting which Commander Dawson has described, yet we shall be open to the remarks of others who go into this question of powder waves if we fail to show that we understand that the elastic fluid passes in every direction and exerts in every direction the same pressure at the same time. Captain Scott, whose system deserves our closest investigation, foresaw that the shot must be centred: he was the first within my recollection to talk of the centering of a shot; he was the first to show us how we could do so by long bearings, by carefully brought-out inclines with those bearings, so that the shot once started into motion, would have no other tendency than to support itself evenly from point to base in the true axis of the bore, and that under these considerations, no wriggling, as Commander Dawson prefers to call it, could take place, and the shot would pursue its even path with the pressure behind it due to the increments of pressure coming either from pebble powder more slowly, or from fine grain powder more quickly. I entirely concur with Commander Dawson in everything he has said as to the utter nonsense of talking about waves of gas being excited by any other cause than suddenly increased pressures due to obstacles. Powder gas like all other gases does never increase sud-

denly in force unless it encounters such obstacles. That the guns hitherto made have not been made with different forms of rifling, I regard as a subject for the greatest regret. The guns which we might in future try, though they may not require to be either re-rifled or re-lined and re-made in the extraordinary way which Commander Dawson has spoken of, might be tried at no great expense to the country with different kinds of shot. I do not think that while we have such results as these, it is wise to ignore the fact that with the long bearing, however made, we have never yet had any destruction either of the shot or the gun. Let us try whether in those guns, without the increased spiral, which we know only last a certain number of rounds under present circumstances, the introduction of different shot will stop that destruction and enable us to trust to our guns for a greater number of rounds. I may state that there is a remarkable difference between the shot exhibited as Captain Scott's and that exhibited as Mr. Vavasseur's, and it consists in the fact that if you take a cylindrical body of iron and cut pieces out of it whether in the form of stud holes or long grooves, you weaken that body; but that where you get long bearings cast on the shot you have two advantages—you do materially strengthen either shot or shell in certain lines, and you do also prevent those shot, if they are being knocked about and receive the damage due to careless handling, from being so likely to ruin your guns, though constructed on the best principles. I think the weight of this Institution, if it is brought to bear in any direction, ought to be given to the advocacy of more extended, more careful, more close experiments than have yet been made with more natures of shot. What we shall do with the guns afterwards in the way of getting rid of an idea of increasing spirals I won't say. If we consider the shot as issuing from the bore with a gradually increasing velocity, we shall see that even an even-spiral gives an increasing twist or speed of rotation in so many parts of a second to the shot in proportion as the speed of the issuing shot is itself increasing. It will do so very injuriously if at any point by reason of the bearings being short bearings, there be a wriggling of the shot in the bore, and where the spiral increases in the gun, with an even spirality of studs on the shot, as Commander Dawson has beautifully described it, you have to find out at which point to make your compromise between the two spirals. He has said, I think with perfect truth, that the increasing-spiral is the reason for the affection which exists at Woolwich for the studs; we cannot have a long bearing which we should like, simply because we have the increasing spiral. The increasing spiral again rests on theory, and has not succeeded in practice; the opposite is just the condition of the long bearing and even-spiral; it has not been advocated much in theory, but it has proved itself in practice. Now, as I have always been of opinion that an ounce of theory is a very good mixture with a pound of practice, I hope we shall have in future a little less of the first, and a little more of the second in this case.

The CHAIRMAN: I will, with your permission, return the thanks of this assembly to Commander Dawson for the very able paper which he has read to us.

There not having been time for Captain Dawson to reply to the remarks made in the discussion, he wishes the following note to be added:—

NOTE.—Commander DAWSON wished to express his thanks to those gentlemen who took part in the discussion, and, with reference to some observations made, to point out that the whole of the erosion or roughness caused by the escaping gases about the seat of the projectile was in the upper part of the bore, and none whatever below the shot. In those rare instances in which roughness or erosion from the gases was found in the lower side of the bore, it never extended inwards to the seat of the base of the shot. The reason of this appeared to be that the fouling matter from former discharges filled the spaces below the shot in its seat, and that nearly all the windage was above the seat, the upper grooves being only very partially occupied, whilst the initial stages of combustion took place on the upper side of the cartridge, and the first gases evolved naturally rose in the bore, and strove to escape through the wide grooves and open space above the shot. The initial movements of the shot were influenced by this initial stage of the process of combustion; but, no doubt, when this less-than-momentary stage was passed, the shot would be enveloped in the gases, as was noticed in some Woolwich-rifled

guns by a slight degree of roughness in the lower side of the bore outside the seat of the shot. The "oblique movements of the axis of the projectile" about its studs were, however, initiated vertically and horizontally before the shot had moved more than eight inches forward.

If we suppose that the shot, balanced in unstable equilibrium upon two studs, was surrounded by equal pressures of gas before it began to move, then the forces we should have to deal with would be simply those of a pressure against the base, and the resistance of friction and gravity acting through the lower rear-stud. The resultant of those two forces would be represented by a line from the lower edge of the base to a central point above the rear-stud. This resultant of forces would operate so as to throw the base up, and the point down, causing the front stud to hammer downwards in its seat instead of upwards; but still equally causing the vertical "oblique movement of the axis" referred to by the learned Professor of Artillery. We should in that case look for the "cracks," "fissures," "dents," "local enlargements," and other damages near the seat, in the lower side of the bore, and not in the upper. Now, as a matter of fact, in the late 35-ton gun, only two "cracks" are found "down," and all the other injuries are "up;" whilst one of these two "cracks" being *on the edge of the lower groove* would appear to have been due to the rear-stud coming into bearing, and not to the front studs hammering; the other crack "down" is in the *centre* of the groove, and might properly be ascribed to the front stud. On the other hand, the other *edge of a groove* found cracked is "up," showing that the shot *jumps* and does not act uniformly in the lower side of the barrel in accordance with the laws of gravitation. Moreover, it is generally found that when other "Woolwich" rifled guns are so eroded as to be obliged to be turned upside down and re-vented, the base of the shot partially obliterates the scoring at the seat, showing that at starting the base is thrown downwards and not upwards. It was a consideration of the marks found in the 35-ton and other "Woolwich" guns, which led me to reject the idea that the shot was enveloped on all sides in equal pressures of gas before starting, and to suppose that its initial movements were influenced by the initial stages of combustion. Speaking generally, I am inclined to regard the damages above the seat of projectiles as inflicted by the front studs, and those found below the seat, as the suicidal work of the rear-stud. Though invariably operating in the same longitudinal part of the bore, the vertical action of the studs is evidently erratic, as the position of some of the cracks and fissures in Woolwich-rifled guns, occasionally tally with that explanation which I have thought fit to reject, but which Captain Selwyn thinks most correct. The distinction between the two vertical actions, viz., of the gases acting above the base in its seat, and of their equally enveloping the shot before starting, is on scientific grounds worthy of careful investigation; but as to the practical question, Captain Selwyn and I are quite agreed that the 35-ton gun was disabled by the action of the front and rear-studs, within a few inches of their seat in the bore; and that the high and erratic powder pressures registered 3½ to 4 feet off, at the inner end of the barrel, were the natural result of the "oblique movement of the axis of the projectile" about its studs at the point where these injuries are found; and that such "wriggling" would increase in force, offering a greater obstacle to escape, in proportion as the "roughnesses," "cracks," "fissures," "enlargements" and "burrs" enhanced the friction upon the rear-studs; and that such increased severity of "wriggle" would lead to still further irregularity in the powder pressures.

LECTURE.

Friday, January 31st, 1873.

Colonel SIR GARNET J. WOLSELEY, C.B., K.C.M.G., Assistant Adjutant-General, in the Chair.

MARCHES.

By Major G. Pomeroy Colley, 2nd Queen's, Professor of Military Administration and Law, Staff College, Sandhurst.

When I undertook to deliver a lecture at this Institution on the "March of an Army," I felt the difficulty which must occur to most who speak here. I knew I should probably be addressing many Officers of much more practical experience in the subject than I could pretend to, and that I was to be honoured with the presence in the Chair of an Officer who himself planned and successfully carried out one of the most brilliant expeditions in our annals. But I thought that this subject, the "Science of Marches," especially as applied to the movement of large masses under modern conditions of war, hardly received the full attention it merits, and hoped that my few remarks, however imperfect, might lead others to carry the subject further, and give us the benefit of their practical knowledge.

We commonly class operations of war under two broad heads—Strategy and Tactics. But there is a third intermediate branch, recognized more generally a little time ago than it is now, namely, "logistique," or the science of marches. The first—strategy, deals with the great conceptions which govern the plan of campaign; the second, "logistique," with the scientific combination of marches, the calculations of time and distance, and of economy of men's powers, by which the strategical conception is worked out to the desired consummation; and, finally, "tactics" step in to reap the fruits of these combinations. Their relative importance may fairly be placed in the same order. Strategy stands highest by universal consent, but the second place is commonly assigned to tactics. Yet many campaigns are decided almost without fighting. Our three most recent and successful expeditions were essentially marches. The Ulm campaign was won by marching, and no tactical skill could have altered the result. It was not so much to his own superior strategy, or to the faults of his adversary that Napoleon was indebted for his brilliant success, as

to the astonishing rapidity of the march across France. If the Russian armies had marched as quickly to the assistance of their allies as the French did against them, the campaign would have been fought out under very different conditions.

It is true that railways have to some extent superseded marches, and that the first result of the campaign will usually be decided by pure strategy and superior organization, rather than by logistique. But even in the last war, many operations turned simply on marching power. Thus in the operations before Sedan, if MacMahon's forces could have marched as rapidly as those of the Crown Prince, the immediate object of the movement—the relief of Metz, would doubtless have been attained. I say nothing of the ultimate results, which probably would not have been very much affected. We hardly realise how seldom tactics alone, independent of superior numbers, armament, or quality of troops, determine the result of a campaign. Even Napoleon's genius could rarely turn the tables on the battlefield when the numbers were against him. Lastly, the casualties of a march often far exceed those of a battle. I shall have occasion to refer to this in speaking of Napoleon's advance into Russia. And, therefore, from the point of view of economy of life, the march requires as careful study as the battle.

There is certainly no lack of interest in military matters among us at the present moment. Questions of all kinds are freely discussed, not only in professional publications, but in all the most influential newspapers. Works on strategy and tactics have recently appeared, that any army may be proud of. But it is to tactics that attention has been principally directed. It is natural that it should be so. The incidents of a battle have a stronger interest than the details of the weary marches that preceded it. Moreover, any Officer may bear an important part in bringing about a tactical result, while the organization of marches rests in the hands of a few. The Wellington essays and others treat fully of what may be termed the tactics of marches; but very little has been written on their organization. Abroad, this is treated as a distinct subject. Important works are specially directed to it, such as the two from the pen of General Gallina, the Chief of the Austrian Staff. "Die Armee in Bewegung," and "Technik der Armee Leitung." It also forms an important part of their practical staff instruction. "Skeleton manœuvres" are carried out annually by staff and other Officers, at which all the necessary calculations of time and distance, the formation of columns and their distribution to the several roads, and the issue of all necessary orders, are worked out as they would be on active service. I may perhaps be allowed to mention here that this kind of practical instruction has been introduced for the last two years at our Staff College, and seems to work very satisfactorily.

But in all military questions in England, whether larger ones of national organization, or smaller ones of individual instruction, we labour under a difficulty which our critics hardly allow for—the varied nature of the duties expected of us. An English Officer's education has to be much broader than that of any foreigner. A German

learns certain lessons in tactics, marching, outpost duties, bivouacks, &c.; he practises these every year at peace manœuvres, and when he goes to war whether it is against France, or Austria, or Russia, it is all the same—he has only to apply them. An English Officer may have learnt these principles just as thoroughly; but the first war he is engaged in, is probably one of bush-fighting in New Zealand or Africa, or against fanatics in India, where all that he has learnt goes for very little. What forms the complete education of a foreign Officer is only a fraction of that of an English Officer. And so it is with the subject of my lecture. A lecture on "marches" addressed to English Officers, to be complete, should include bush-marches, Indian-marches, Abyssinian-marches, a hundred kinds of marches. But a dozen lectures would not suffice, even if one man could deal with so large a subject. I propose, therefore, to confine myself in this lecture to the marching of large bodies of troops in ordinary civilized countries—to such points as arise in a great European war.

All combinations of marches turn on accurate calculations of time, distance, and the marching power of men; and it is therefore necessary first to determine what distances can be traversed by troops within given times. All nations allow about the same average rate of marching, viz., $2\frac{3}{4}$ to 3 miles an hour for infantry,* 4 miles for field artillery, and 5 for cavalry and horse-artillery. This includes short halts of five minutes or so, and represents the pace at which they can get over fair marches with least fatigue. But these rates apply to small bodies only. With large bodies, the rate is slower, for every check is felt throughout the column, and multiplied by the length of it. Thus a division of infantry can seldom accomplish more than $2\frac{1}{4}$ to $2\frac{1}{2}$ miles an hour, and a corps on one road even less—2 miles an hour; the infantry, as the slowest marchers, regulating the rate of the whole. And even this rate can only be depended on on good roads and with good arrangements; if the roads are bad, or crowded, it is still further reduced. Thus Vandamme, marching from Ligny to Wavre, and the Prussians marching from Wavre to Waterloo, could only accomplish about $1\frac{1}{2}$ miles an hour, owing to the bad state of the roads. Napoleon's troops—trained marchers as they were—could sometimes only accomplish eight or nine miles in as many hours in the sands and mud of Poland. At Magenta, when support was urgently required for the Guard, it took five hours to bring up Canrobert's corps from Novarra, a distance of 9 miles. The road in this case was excellent, but encumbered. In 1866, before Sadowa, the 8th Austrian corps took 14 hours to do 12 miles. In 1870, when the Crown Prince was following MacMahon northwards, his troops were sometimes on their legs from four in the morning till eight at night; yet it is doubtful if they ever accomplished 24 miles in one day.

The average day's march is usually estimated at 12 to 15 miles, with a halt every fourth or fifth day. From 15 to 20 miles are long marches,

* The Italians, who devote special attention to the marching of their men, allow a somewhat higher rate. See "Istruzione per l'Ammaestramento Tattico delle Truppe di Fanteria," p. 161.

and are seldom kept up many days; and anything over 20 miles may be treated as a forced march. To a good walker, these distances may seem small; but it must be remembered they only represent a part of what is done by the soldier, who may have to go a mile or more off the road to his billet or camp, to patrol during the march, or go on outpost, and mount sentry after it, besides performing the numerous minor duties of a camp: in all cases he carries a heavy weight, and moves under conditions very different to those of the ordinary pedestrian.

To form an estimate of what troops may be expected to do in a long campaign, I have carefully gone through the records of the most celebrated marches of ancient and modern times, verifying them where practicable. The actual daily average has seldom exceeded 10 miles (including halts), or 14 for marching-days only. Of ancient marches that of Xenophon and the 10,000 Greeks is the best known, and perhaps the most remarkable. The march from Sardis to Cunaxa, near Babylon, was about 1,400 miles, and accomplished in five months' marching, or a little over 9 miles a day. The retreat to the Bosphorus was considerably longer owing to the detour made, and the rate slower, the Greeks being constantly harassed on the march. The total distance gone over, is estimated at about 3,500 miles, and took fifteen months, being about 8 miles a day.

Xenophon's experiences agree fairly well with our own. A good day's march under favourable circumstances seems to have been 16 to 18 miles. When in presence of the enemy and in fighting order, this was reduced to 10 or to 13 miles. Occasionally to cross deserts, &c., they did from 24 to 26 miles in the day; but a few such marches were always followed by a good rest.

Alexander's armies traversed greater distances, but his campaigns present no such long continuous marches. They were rather a series of eager advances or pursuits, and long halts. With his infantry, he seldom exceeded 14 miles a day for any length of time. He accomplished some wonderful feats in the pursuit of Darius, but in these cases his infantry fell behind, and he was generally left at the end with his cavalry only, and often very little of that.

Among modern marches, that of Napoleon's army, in 1805, from the shores of the Channel across France to the Rhine, and thence to Ulm, stands pre-eminent. There is no difficulty in verifying this march. We know the days of arrival and departure, and can measure the distances. Fezensac and other writers give many details of it; and through the kindness of the Baron de Grancey and the French War Office, I have been put in possession of the actual march-routes of some of the columns, showing each night's halting-place. The distances traversed by the several columns varied slightly, but averaged about 400 miles, to the Rhine; the time taken averaged 26 days. This gives between 15 and 16 miles a day, or, if allowance is made for halts, nearly 20 for every marching day. The three corps from the camps near Boulogne marched by distinct routes; each corps marching by divisions at one or two days' interval. The troops reached the Rhine punctually, and in perfect condition, with almost incredibly few casu-

alties, and immediately crossed and continued their march on the Danube.*

This was an exceptional feat, and stands alone; but Napoleon's movements generally were more rapid than those of his predecessors had been, and to that he owed much of his success. Marlborough's most celebrated march was that made in 1704, by which he transferred his army from the Netherlands to Bavaria, joined Prince Eugene, and won the battle of Blenheim. The distance continuously marched was 240 miles, done in 25 days, or a little under 10 miles a day. Frederick's movements were slower still; his best-known march is that from Rossbach after defeating the French there, to Leuthen, where he defeated the Austrians; but he averaged under 8 miles a day.

The best march in the last war was that of Prince Frederick Charles with the second army from Metz to Fontainebleau and Orleans. The average rate seems to have been 12 or 13 miles; but the 9th corps marched more rapidly, being hurried forward in consequence of the French advance. The last few days of its march, from Troyes to Fontainebleau, averaged as much as 19 miles. To do this march justice, it must be remembered that it was made in an enemy's country, infested with Franc-tireurs, was harassed by obstacles on the roads, and was sometimes seriously opposed.

By comparing a number of marches, I arrived at the conclusion that 10 miles a day is as much as should be reckoned on in prolonged operations, and from 12 to 15 miles for actual marching days; and these calculations agree curiously with the account of the operations of the 5th German Corps in the late war, just published. It appears the distance actually traversed by this Corps between the Rhine and Paris was 520 miles in 50 days, or $10\frac{1}{2}$ miles a day. The average for actual marching days was $13\frac{1}{2}$ miles, with a halt usually every fourth day; and the longest day's march was 21 miles, being made during the pursuit of MacMahon's army northwards.†

Forced marches, though often brilliant feats in themselves, have not the same practical value for strategic combinations. St. Cyr calls them the resource of an improvident General, but rarely used by a prudent one; and says their too frequent use soon destroys an army. Moreover, men's powers, in this respect, are much overrated, and few of the most celebrated marches will bear investigation. A single march is so easily exaggerated or misrepresented, even unintentionally. A body of troops marches, say at ten one morning, does 20 miles that day, has a full night's rest, and marching at four the next morning, reaches its destination, 15 miles distant, by ten. For all practical purposes this is merely doing 35 miles in two days' march. But a friendly historian, to make it sound better, says they accomplished 35 miles in twenty-four hours, and the next friendly historian, not observing the delicate distinction, says they

* Accounts of this and other marches of Napoleon's are given in Dumas', Thiers', and other general histories; but the most interesting details are to be found in personal narratives, such as those of Fezensac, Labaume, Dr. H. von Brandt, &c.

† "Das V. Armee-corps im Kriege gegen Frankreich," 1870–71. Stieler von Heydekampf.

did 24 miles in a day, and so it goes down to history as a remarkable forced march. I am sorry to say one of the first results of my investigations was to throw the gravest doubts on the celebrated march of the Light Brigade before Talavera, so familiar to students of Napier, and so frequently quoted to show what British troops can do. Napier's account of it is as follows:—

"That day (29th July, 1809, the day after battle of Talavera), "Robert Craufurd reached the camp with the 43rd, 52nd, and 95th "regiments, and immediately took charge of the outposts. Those "troops had been, after a march of 20 miles, hutted near Malpartida "de Plasencia, when the alarm caused by the Spanish fugitives spread "to that part. Craufurd, fearing for the army, allowed only a few "hours' rest, and then, withdrawing about 50 of the weakest from the "ranks, recommenced his march with a resolution not to halt till the "battle-field was reached. As the Brigade advanced, crowds of the "runaways were met with, not all Spaniards, but all propagating the "vilest falsehoods: 'The army was defeated,' 'Sir Arthur Wellesley "'was killed,' 'The French were only a few miles distant;' nay, some "blinded by their fears, pretended to point out the enemy's advanced "posts on the nearest hills. Indignant at this shameful scene, the "troops hastened, rather than slackened, their impetuous pace, and "leaving only 17 stragglers behind, in 26 hours crossed the field of "battle in a close and compact body, having in that time passed over "62 English miles in the hottest season of the year, each man carrying "from 50 to 60 lbs. weight upon his shoulders. Had the historian "Gibbon known of such a march, he would have spared his sneer "about the 'delicacy of modern soldiers.'"*

Now, there is an inconsistency even in Napier's account. The distance from Malpartida de Plasencia to Talavera is 62 miles; consequently, the actual distance marched would be 82 miles,—a still more wonderful feat. Through the kindness of a distinguished Peninsular Officer, himself present on the march and an experienced Staff Officer, I have been put in possession of what I believe to be the actual facts, which are as follow:—

The Light Brigade reached Malpartida on the 25th, three days before the battle. On the 26th and 27th they made two short marches, marching early in consequence of the heat of the weather. On the 28th they had completed their day's march early when they heard of the battle. Craufurd waited till the heat of the day was past, broke up in the evening, gave his men a halt during the night, and reached the battle-field about sunrise the next morning, the actual distance traversed from the halting-place on the night of the 27th being 40 miles. Finding the battle over, the brigade halted and rested; and in the afternoon crossed the battle-field and took up the line of outposts.

Sir William Napier did not himself take part in this march; he was taken ill a day or two before, and was taken back to hospital by his brother George, and it seems to have been the extraordinary march made by the latter to overtake and rejoin his brigade which the

* Napier, ii, 178.

historian confused with the march made by the brigade itself. The authorities by which the version I have given of the march are supported, are the following, viz., the notes and recollections of the Officer I have already referred to; journals of other Officers who, like himself, took part in the march; returns which are, or recently were, at the Horse Guards, showing that the Light Brigade was at Malpartida on the 25th, three days before the battle; and the statement of one writer, that he was with the Light Brigade in every march throughout the war, and can safely assert that neither they, nor any other troops he ever met with, could have made such a march.

The most extraordinary feat in ancient or modern history, if we can believe it, was the march made in the Second Punic War, by which the Carthaginian power in Italy was finally broken. The circumstances are familiar to most students of Military History, because it is the stock example quoted by writers on strategy to show that the true principles of strategy, and of interior lines, are as old as war itself, and were understood and applied by the ancients. The Consul Claudius Nero, with a Roman army, was facing Hannibal, who had taken up a position at Canusium, awaiting the arrival of his brother Hasdrubal, with the reinforcements he was bringing from Spain. The Consul Livius Salinator, with another Roman army, was opposed to Hasdrubal at Serra Gallica, near the Metaurus. Having intercepted all communications between the brothers, Claudius determined to try and crush Hasdrubal while isolated; he accordingly set out secretly from his camp, with 1,000 cavalry and 6,000 infantry, the *élite* of his army, leaving the rest to oppose Hannibal. In six days of forced marches he joined his brother Consul, with their united forces attacked Hasdrubal, utterly defeating and killing him, and immediately started south again, accomplishing the return journey in the same time and regaining his camp before Hannibal had discovered his absence. Now, the distance fairly measured, is 240 miles, or at the rate of 40 miles a day for six days, both going and returning; and making every allowance for the assistance said to have been derived by requisitioning carts and horses along the road, it is very hard to believe in such a march. It is a curious and instructive fact that the two ancient campaigns, of which we have most authentic accounts, Xenophon's march and Cæsar's Gallic wars, where the General himself is the historian, are those in which we hear least of extraordinary forced marches.

Hitherto I have spoken of movements of columns of all arms; of remarkable cavalry marches there are many authentic records. One of the best known is that of Charles XII from the Vistula to the Oder in pursuit of the Saxon Army, when he marched over 30 miles a day with all his cavalry for nine days consecutively. The distance is not exceptional, but it was done with a large force of cavalry, and over bad roads. But I believe that the records of our Indian wars, of Lord Lake's Mahratta campaigns, and, more recently, of some of the flying columns during the mutiny, contain the most remarkable examples of such feats. Unfortunately, from difficulty of finding the places on the map, and identifying names, it is often impossible to verify them.

The next point to be considered is the space occupied by troops on the march, as it is the length of the column which causes the difficulty in moving and feeding large bodies of troops. I need not trouble you with the calculations, which any one can make; but a good practical rule for a Staff Officer in the field is to allow a yard for every one horseman and for every two foot soldiers, and 20 yards for every gun or waggon. The difficulty is to know how much to allow for unavoidable opening out on the march. This is variously estimated by different writers at from 5 to 60 per cent., rather a serious margin of error.* Verdy du Vernois does not think it necessary to make any special allowance; while Colonel Lewal, a French Staff Officer, estimates it at two-thirds the proper length of the column, and quotes examples from the Italian war of 1859 in support. Perhaps the nationalities of the writers partly explain their difference of opinion. The Prussian troops close up on the march better than any troops I know: on the other hand, the French, though really excellent marchers, are notorious stragglers: their own Officers acknowledge and complain of this. A Prussian Staff Officer, to whom I showed Lewal's calculations, answered at once "He is probably right; but it does not say much for the discipline of his troops." Probably we shall be right if we take an intermediate estimate, and allow about 25 per cent. On this calculation an English infantry division on war establishment with its full train occupies about 12,000 yards. During the autumn manœuvres of 1871–72 I had several opportunities of measuring the length of columns of march, and found the above calculations fairly correct, exceps in the case of hired transport. I was much struck with the difference of length of a column of regimental transport as organized last year under experienced baggage masters, and the columns of hired transport of the year before.

The Austrians advocate considerable intervals between regiments and brigades, and there is much in favour of this system. If a regiment unavoidably opens out to the extent of one-third or one-fourth of its length, it seems better to allow the next regiment to start with a corresponding interval. The ultimate length of the column will not be increased, and the heads of regiments will be able to maintain a uniform pace as if marching independently, and avoid the constant checks and changes of pace so fatiguing in long columns.

The order in which the column of march is formed must necessarily depend on various considerations, such as the object of the march, the nature of the country, or the vicinity of the enemy. But two great principles should always be adhered to. The first is that when in presence of the enemy, everything must give way to tactical considerations; when at a distance, the ease and comfort of the men must be first considered. The second is that everything should be arranged in the column in the order in which it is likely to be wanted.

A column in presence of the enemy is always preceded by an advanced guard, whose duty it is to save the main body from surprise or from being made to fight under unfavourable circumstances. Consequently,

* See Wolseley's "Soldier's Pocket Book;" Verdy du Vernois "Studien über Truppen Führung;" Colonol Lewal "Conférence sur la Marche d'un Corps d'Armée."

as the range of weapons increases, and battles are fought at greater distances, so must the range cleared by the advanced guard be increased. In these days, if a battery of artillery is allowed to march along an ordinary enclosed road within 1,500 yards of the head of the advanced guard, it might be annihilated by an enemy's battery suddenly unmasked. The point of the advanced guard must be partially liable to surprises, and therefore is made small and mobile, cavalry being always chosen for this duty, if possible. This "point" is supported by somewhat stronger bodies at suitable intervals, but no large body of troops, and no wheeled vehicles (except perhaps a couple of guns without waggons, or a light cart with entrenching tools) should be allowed to come within effective artillery range of the head of the advanced guard, or of any point which has not been reached or overlooked by them or by the flankers. The detailed formation of the advanced guard is a tactical question which does not come within the scope of this lecture.

The main column follows, the artillery generally near the front, ready to perform its rôle of opening and preparing the battle. The bulk of the infantry follows, each regiment accompanied only by its ammunition carts and tool waggon. The cavalry, if not with the advanced guard, generally follows in rear of the infantry. The train then follows, arranged on the principle given—first, that which may be required during the action, the reserve ammunition and the ambulance detachment; then what will be most urgently supplied when the battle is over, the day's supplies; then the staff and regimental baggage; and, lastly, the reserve supplies and miscellaneous stores.

If no enemy is near, these arrangements may be modified to ease the men. The cavalry and artillery are separated from the infantry, as nothing is so fatiguing to the former as having to conform to the pace of the latter. If possible, they are given distinct roads, or allowed to march independently. When there is a choice of hours the mounted corps should move latest, as they take longest to prepare, and the horses do not feed so well at very early hours. The supplies and baggage may be brought more forward, and reserves of ammunition and field hospitals put further back.

It has been shown that a British infantry division on war establishment occupies about 12,000 yards, or seven miles, of which half is taken up by the combatants and half by the trains. This represents about $2\frac{1}{2}$ hours in time, that is, the column will take that time to pass any given point. Such a force can march in one column without any serious inconvenience or fatigue to the troops, or administrative difficulties. Napoleon's march to the Rhine in 1805 was by divisions, as was also a great deal of the marching in the late war. It is true the leading troops will have to wait at least an hour and a half for their baggage, but a certain time is necessarily spent in laying out the camp, collecting firewood, &c. If the troops have started at six and made a fifteen mile march—which, including a long halt, takes seven hours—they arrive between one and two, get their baggage between two and three, and are all settled by four. If the troops are marching in small bodies everything is still simpler.

But if even two divisions are marching on one road the inconvenience and delays become serious. The tail of the column will not be in till six, and the men will hardly get their dinners before dark, and if the weather is hot the second division will always suffer from marching during the worst hours, however early the first division starts. And if a whole corps has to use one road the difficulties and the fatigues are immensely increased. The tail cannot in any case be up till the middle of the night. If the divisions are followed by their baggage the last troops are not in by dark. If the baggage is massed in rear, the troops get in earlier, but are kept waiting many hours for their baggage and supplies. Nor is it exceptional for a whole corps to move on one road. It happened occasionally in the last war, though generally separate roads were found for each division. In 1859 the French had sometimes to march more than one corps on a single road, the number of good roads in Lombardy being limited, and the intervening country difficult to cross in consequence of the vineyards and ditches. In 1866, during Prince Frederick Charles's advance into Bohemia, he had at one time only two roads for four corps d'armée, and the difficulty of moving and feeding the troops under these circumstances is specially remarked on in the Prussian official account. In the invasion of Russia, Napoleon sometimes had to move 50,000 men on one road. The inconvenient hours of march, the long halts, the tedious delays, the irregular hours, the uncertainty of supplies, cause what the Germans term the "friction" which always attends the movement of very large bodies of troops. What the effects of that friction may be, we learn from Napoleon's invasion of Russia. From the Niemen to Smolensko is about 400 miles, the same as the march across France already quoted. The time occupied was 50 days, just twice as long. The troops had two long rests at Wilna and Vitepsk, and on actual marching days did not average more than 12 miles. The weather was hot, but not generally unfavourable, and the march was a triumphant advance almost without fighting. Yet the central column lost 90,000 men, solely from the fatigues and hardships and "friction" arising from crowding so many men on a limited number of roads.

The great object in arranging marches, therefore, should be to spread over as broad a front and occupy as many roads as possible consistent with safety; and where long columns must be sent on one road, to reduce this "friction" to a minimum by careful arrangements. In dealing with the first we have to decide what are the limits of safety. And here I must diverge into what is strictly a tactical question, but exercises a powerful influence on march-dispositions. Formerly it was generally accepted that when the armies were separated by at least a day's march it was sufficient if the whole force could be concentrated in a day, but that when collision was imminent, the marching front should not much exceed the fighting front. But I conceive that new tactical conditions, the increased retaining power of small bodies, and the increased value of flank as compared with front-attacks, have modified the latter rule, and that it should now be a maxim always to march on a considerably broader front than would be occupied in fighting. Thus if a corps of 20,000 men marching in a single column came

in collision with a corps of the same strength marching in three small columns separated by distances of six or seven miles, under former conditions the latter would probably be defeated in detail. The central column would find itself engaged with very superior forces; if it fights in a compact formation its flanks would be turned; if it extends to save its flanks, its centre could be pierced by superior weight, in either case probably before the adjoining columns could render effective assistance. But under present conditions, the central column could afford to extend to a much greater distance to guard its flanks; any attempt to pierce the centre by superior weight would be uncertain, and could only be attempted after long fire-preparation, during which time the flank columns would be closing in; and when these do come into action they do so in the most effective manner, namely, on the flanks of the adversary, who, in all his attempts to deploy, finds himself already outflanked, and in somewhat the position the French found themselves in on their sorties from Metz and Paris.

But it will still happen that long columns have to move on single roads, and that special arrangements become necessary to reduce the consequent discomfort and fatigues. Something may be done by marching the column on a broader front; but few roads admit of this. The cavalry may sometimes be sent across the fields; and in Bohemia and France, where there are few fences, the infantry often marched alongside the road, leaving the road clear for guns and carriages of all sorts. In enclosed countries bye-roads or lanes may be turned to account; such usually exist between the more important roads allotted to the several columns. But they are subject to several drawbacks. They are generally zigzag, consequently longer, and troops are more likely to go astray on them. There is always the risk of two neighbouring columns trying to use the same, and so coming into collision; the general or superior staff indicates the main line to be followed by each column, but cannot define how every little lane is to be used. It introduces, moreover, a dangerous element of uncertainty in time; on a good road calculations of time may be made with tolerable certainty, independent of the weather; but on bye-roads and lanes an unexpected fall of rain may upset all calculations.

Columns of more than one division are therefore generally made to march in echelons, or "staffeln," as the Germans call it; that is broken up into distinct bodies, moving to a certain extent independently. A division occupies seven miles of road. If a second division, following it, instead of closing up each night on the head of the first division, halts at a distance of seven miles in rear, the two divisions will form a continuous column on the march, but will be able to start simultaneously, reach their camping grounds at the same hour, get their baggage up at once, and in all respects work as independent columns. This system at once meets most of the objections to moving many troops on one road, and is that commonly adopted when not in presence of the enemy. But when close to the enemy, the extension is too great. If an English Army corps, with its three divisions of infantry, and corps artillery and cavalry equivalent to a fourth, is moving in this order on one road, the distance from the first to the fourth encampment will be 21 miles; and

if the leading column is attacked on the march, the rear ones could not close on it in the day. To obviate this, "reduced," or "half" intervals are used; that is the several divisions halt at distances equal to half the length of their column of march, or $3\frac{1}{2}$ miles apart. This is, in fact, a compromise; the troops do not move with the same freedom and comfort; the second division must start an hour or more after the first, or it would run into the tail of its column, and the other bodies must delay their march still further, and reach their camping grounds proportionately later. On the other hand the distance between the first and fourth camp is only $10\frac{1}{2}$ miles, and the corps can always be concentrated in the day.

There is another system mentioned by General Gallina, the Austrian chief of the staff, and which I believe was sometimes adopted in Italy, being specially applicable to cases where the climate makes it necessary to avoid the hottest hours of the day, and yet large bodies have to be moved in concentrated order. It is to marching by *alternate* echelons. The four bodies having encamped at half intervals, 1 and 3 move at a very early hour and simultaneously, 3 passing through the camp of 2, and reach their destination before the full heat. 2 and 4 march in the afternoon, and reach their camps late, regaining their original relative position. This method may also be adopted in passing a short defile, or when two parallel columns have to use one road for a time.

*Supply on the March.**

Any notice of marches must be very incomplete if it does not include the feeding of troops on the march, as it is this which often really governs the march-dispositions. The supplies carried by an army may be classed under three heads:—Those carried by the soldier, or regimentally, and which are always at his hand; those carried in the divisional provision columns, and the reserve supplies or field magazines which follow in rear of the Army.

The Prussian soldier carries constantly three days' reserve rations, "*eiserne* portion," as it is called, as part of his kit in his knapsack, consisting of biscuit, rice, and bacon. Besides this he carries common rations according to circumstances; usually one day's, but often more. The Austrians carry two days' reserve, and two days' ordinary rations; the Russians, four days' bread or biscuit; the French, generally three to six days' biscuit. We have no regulations on the subject. The question was raised during the autumn manœuvres, and some say that the British soldier cannot be made to carry his rations, that it is contrary to his habits and prejudices, and that we can only accept the fact, and carry them for him. I fear in any great European war he would have to overcome this prejudice or starve. In our distant expeditions, where the fighting columns are comparatively small, and the enemy not so formidable, the distance between the men and their supplies need not be great. But in European wars, when large armies are moving concentrated, and in presence of a powerful enemy, it is different. Every account I have been able to collect, whether of our own

* See Obauer and Gultenburg's "Train und Verpflegs-wesen."

Peninsular experiences, or of more recent European wars, agrees in stating that in presence of the enemy the day's supplies can never be brought up till late, often barely in time for distribution before the troops start the next morning. In the German war the troops on the march lived mainly on the inhabitants; but when concentrated for battle they depended entirely on the rations carried by the men, which could only be irregularly replenished from the provision column.* It has been proposed to attach a special cart to each battalion for the purpose, as was done at the last manœuvres, and as the Austrians are also doing. This has much to recommend it; but it must also be remembered that every additional waggon seriously hampers the fighting column, and in the urgency of battle it would often be pushed aside and unable to regain the battalion. The Prussians and Austrians have canteen or suttler's waggons, "marketender wagen," to each battalion, and generally allow them to accompany the battalion. The canteen man is a professional forager, who understands his business, and has nothing else to do, and manages to pick up supplies in a wonderful way when others fail. The Prussians would often have been in a bad way but for their canteens. Still these cannot be trusted to; and it may be laid down that the soldier is never safe, and the Army cannot be depended upon for any sudden operation unless the men always carry at least one day's rations.

The second line of supplies is that carried in the divisional provision-columns. In all continental armies there is a regular service organized for the purpose, of *military* transport, sufficient to carry four days' supplies. We have no such organization at present. In Prussia they are termed "proviant colonnen": they form part of the corps organization, but are usually attached to the divisions, two to each. In Austria, they are formed partly of divisional transport, partly of regimental waggons, which are worked divisionally, but usually supply their own regiments. They seem to have found that waggons which belong to particular regiments are more careful to find them out and supply them than if they had no such connection. In Russia they are formed of waggons which are kept in regimental charge in peace time, but are massed and formed into divisional columns in war.

The task of these columns is to replenish the regimental supplies; every day at the close of the march, if practicable, but often it cannot be done till late at night, or only on alternate days. When the length of column is considerable, the provision-columns have to make long forced marches, after the others have done, to reach the head of the column, and this often can only be done at night, when the troops are camped and the roads clear. Practically, a great deal of the supply duties are carried on at night, and hence the importance of always keeping the roads clear at that time.

The difficulty of feeding an army lies not so much in procuring supplies as in bringing them to the men. Napoleon had collected ample supplies for his invasion of Russia, yet his troops were nearly

* Some of the recently published histories of the last war give the particular occasions on which the troops were obliged to use their reserve rations. See "Das V Armée Corps," &c.

starving from the very beginning, and this was the primary cause of the immense losses I have spoken of. His cavalry at the head of the column swept the country, and to a great extent lived on it. The rear divisions were supplied without much difficulty from the provision trains. But the leading and central divisions in those enormous columns could neither live on the country nor be reached, except irregularly, by the provision trains from the rear; and theirs was consequently the heaviest loss in stragglers. When large columns are supplied entirely from the rear a halt every fourth or fifth day becomes necessary, not only for the men's sakes, but on Control grounds, to enable the provision columns to refill and the system of supply to be reorganized. A day of battle, or of concentration for battle, is also used for the same purpose.

The second line, or divisional columns, are replenished sometimes directly by requisition, purchase, or from the country, but commonly from the third line or reserve stores. The organization of these, which are also sometimes called field-magazines, varies endlessly, according to circumstances; but they usually consist of hired or requisitioned transport. If, as in late wars, railway-transport can usually be maintained within a day or two of the front a small reserve train suffices; but where armies are operating at a distance from magazines and railways it increases to an enormous extent. These again in their turn are refilled from the great magazines, directly or by means of railways, or by requisition on the country. It is a first principle of supply to draw everything that can be drawn from the country the troops are traversing by free purchase, forced sale, or requisition, and treat the magazines and provision trains as reserves only to be touched in case of necessity. However poor the country, it can generally feed a portion of the army; and if it can only supply the advanced guard or the leading division, a great deal has been gained, for these are precisely the most difficult to supply from the rear.

And now I come to the last branch of my subject, the preparation and issue of the orders for the march. The success of a march must necessarily depend on the care and precision with which the orders are framed. The great principles to be attended to are that the orders shall be clear and concise; that they shall convey such information as will enable subordinate commanders to execute them intelligently, not as mere machines; that they shall define minutely all points where collision between independent authorities might occur, and avoid interfering with details which lie entirely within the province of subordinate commanders.

I can illustrate my meaning very well by a reference to the orders issued to the 3rd, and Meuse Armies after Sedan. The movement on Sedan had been a continuous wheel by which the Army of the Crown Prince, originally on the extreme left, found itself on the west, and consequently on the right in any further movement on Paris. It was considered necessary to correct this inversion in the advance. The first part of the order explains the reasons for a somewhat complicated movement; the second lays down definite instructions where the two

armies might come into collision, but leaves everything within their own sphere of operation absolutely at the discretion of the Army Commanders.*

As models of orders I would quote those of the Archduke Albrecht for the Custozza campaign. They have a special interest, both on account of the brilliant success which attended their execution, and because their author was also the author of that remarkable work on "Responsibility in War," which lays down more clearly and ably than had ever been done before, the true principles of command. They are long, because they deal with complicated operations and many independent commands; but they never trench on the province of subordinate commanders, and they contain in themselves the whole history of the campaign.†

The Prussians have introduced a method into their orders which may seem almost pedantic, but has great advantages. All their orders are framed on the same model. They generally open with a brief statement of the object of the march, and any information about the enemy or the adjoining columns that will be useful. Then comes the hour, direction, and order of march of the column or columns, usually beginning with the advanced guard; their instructions for any flanking parties or detachments; next the orders for field hospitals, reserve ammunition, and fighting train generally; then those for the baggage and supplies; and lastly, the position of the General, or head-quarters. In this manner one knows where to look at once for any required information.

Thus the orders for the 8th Corps, before the battle of St. Quentin (January 15, 1871), run as follows:—

"According to reports received, the enemy has concentrated con-
"siderable forces at St. Quentin, and pushed his outposts towards
"Péronne and Ham. I order as follows for to-morrow:

"1. The 15th Infantry Division will march at 8 A.M. by Jertry to
"Etreillers and its vicinity, sending out patrols at daylight along this
"road, and in the direction of Vermand."

Paragraphs 2, 3, and 4 similarly give instructions for the 16th and reserve divisions and a detachment under Count Gœben. Paragraph 5 contains the orders for the corps artillery; 6, those for the train; and 7 lays down where the General will be found.

The orders issued by Prince Frederick Charles in the advance into Bohemia in 1866 open with full statements of what is known or supposed of the enemy's movements.

This system of explaining the reasons for a movement, of taking subordinates into confidence as it were, which we observe in the Prussian orders, is not I believe usual with us. There is an incident in the retreat from Burgos in 1812, which is related by Napier, and has always seemed to me very suggestive in this respect. It is thus told:—

* See Blume's "Operations of the German Armies in France."

† These orders are given at length in the Austrian official account, "Österreich's Kämpfe im Jahre 1866."

"Knowing the direct road was impassable, he (Wellington) ordered "the movement by another road, longer, and apparently, more diffi- "cult. This seemed so extraordinary to some General Officers, that "after consulting together they deemed their Commander unfit to "conduct the Army, and led their troops by what appeared to them "the fittest line of retreat. He had before daylight placed himself at "an important point on his own road, and waited impatiently for the "arrival of the leading division until dawn; then suspecting what had "happened, he galloped to the other road and found the would-be "Commanders stopped by the water. The insubordination and the "danger to the Army were alike glaring, yet the practical rebuke was "so severe and well-timed, the humiliation so complete and so deeply "felt, that with one proud sarcastic observation, indicating contempt "more than anger, he led back the troops and drew off all his forces "safely."

Fortunately, as it happened, Soult had just suspended the pursuit, and the army escaped what might have been a great disaster. Now there is nothing to be said for the Generals. No comments can be too severe on their insubordination. But it does occur to one that if the orders had been framed on the principles of those I have been quoting from, if it had simply been stated that in consequence of the main road being impassable, the troops would follow another route, the occasion never would have arisen. It is not too much to say that one-half of the cases of misconception or disobedience of orders, arises from want of sufficient confidence in subordinates.

The more we see of the Prussian orders during the late war, the more clearly two principles stand out—perfect confidence between the commander and his subordinates, and non-interference. In urging the principle of non-interference, I know that the example of the two greatest Commanders of modern times can be quoted on the other side. Both Wellington and Napoleon interfered, and constantly interfered in the details of their subordinate commands. But such men are no rule for others. A great genius fashions the tools for his purpose, and uses them well; but they do not work in other hands. It seems to be one of those mysterious laws of Providence, one of those compensating principles, by which the balance of the world is maintained, that the very genius which gives a nation its military pre-eminence in one generation, sows the seed of its decay in a future one. An army which has learnt to draw its whole breath of life from one man soon collapses when he is removed. It is with an army as with a regiment; the true test of its efficiency is that it shall work well under an indifferent commander; and this can only be the case when every subordinate has been trained to full responsibility and independence of thought and action within the necessary limits in his own special sphere. Such a system was forced on Prussia by the disasters of 1806, when the magnificent army created by Frederick the Great, but lifeless without his spirit to animate it, fell to pieces at the first touch. Such a system was urged on Austria after the disasters of 1866 by the Archduke Albrecht; and such a system—fortunately without the warning of disaster—is now being ably and earnestly advocated by many in England. No nation

has so much to gain by it as we have. No race can claim more natural independence and vigour of mind—witness our Colonies, our Indian career, the history of British enterprise all over the world—while our institutions have trained us to combine freedom of thought and action, with subordination to authority. If we can only learn to do justice to our special national characteristics, the stubborn courage of our men, and the independent self-reliant energy of our Officers, assuredly we need not fear comparison with any Army in the world.

SUGGESTIONS FOR A SHELTER TENT.

Contributed by Captain Tulloch, 69th Regiment, Garrison Instructor, Halifax, Nova Scotia.

With reference to the sheltering of troops during active operations, there may be said to be two distinct methods, viz., the English and the French. In the English service, the tents are carried for the men; in the French, the men carry them themselves; whilst the Prussians get what shelter they can without tents at all. There can be no doubt but that the English system is the best as regards the preservation of the men's health, and consequently their efficiency; but, judging from the experiences of the armies during the late campaigns, it would seem more than probable that if an English force be ever engaged in active operations on the Continent, it will frequently—no matter how perfect the transport may be—have to forego the use of bell tents, and be obliged to adopt either the Prussian or the French system. As regards the latter, although it is unquestionably convenient, in that it releases for other purposes a considerable amount of transport, which would otherwise be employed in carrying tents, yet it has several decided objections, the first arising from the circumstance that French soldiers have no other protection from the weather during a whole campaign than that of the makeshift nature obtained from *tentes d'abri*. The second objection is the weight of material which has to be carried by the men. (In our service the regulation *tente d'abri*, when dry, weighs about 12 lbs., that is, 6 lbs. for each man, the material not being divisible into three.)

With reference to the Prussian method, if the weather be fine, bivouacing is by no means so unpleasant as is generally supposed; but if the weather be wet or cold, it is a very different matter; and although the excitement of expecting to meet the enemy may keep off sickness for a time, yet the effect of even a few days' bivouacing in bad weather will tell very severely on the men, and rapidly fill the hospitals. Prussian Officers who served in the Austrian war of 1866 have informed me that the sickness at the close of the campaign was quite appalling, far exceeding what was generally known; they attributed it almost entirely to the maladies consequent upon having no shelter during a

continuance of very wet weather. The immense percentage allowed by the Prussians in calculating the probable number of casualties for a year's campaigning (in which the fire of the enemy is debited with but a small amount), is, I think, a sufficient indication of the waste of life resulting from their system.

If, then, the continental methods above named are so objectionable, what course suggests itself? Certainly there are drawbacks to every scheme, but, all things considered, I think that a very simple plan of giving men cover when away from their tents is possible, by a slight alteration of, and addition to, the waterproof sheets now carried with the tent equipage. These regulation sheets are 6 feet 6 inches by 3 feet, and have each six eyelet holes. By the substitution of six metal studs and six stud holes, and the addition of a divided stick, three small pegs, and two pieces of string, waterproof lean-to's may be erected, which will fairly protect those using them from wet or cold wind.

The weight is as follows:—

	lb.	oz.
Waterproof sheet.	2	2
3 pegs, 2 pieces of string 9 feet (cod line)	0	5
Divided stick (hickory) $\frac{3}{4}$ inch diameter, 4 feet long..	0	10
	3	1

The studs are intended to button on the under side, giving a lap over of an inch; the upper end of the studs (with the exception of the one at the side) to be covered with a small patch of waterproof. The stud holes at the right and left corners should be larger than the others, to receive the small end of the stick. The thin sheet-iron joint of the stick is to be arranged like the sliding measure on the top of a powder flask, so that when not in use, it may slip back on the stick, where it will be held by the little projection; the metal joint will thus be safe from injury.

The accompanying diagram shows the method of buttoning the sheets together so as to form cover for two, or any greater number of men. By buttoning six sheets together, and using six butts and three tips, first-rate shelter can be made for six men; there would be no difficulty in continuing such a shed (three sheets high) for any length required. With fifteen sheets, a double lean-to, or /\ tent, with one end closed, can be formed, $12\frac{1}{2} \times 12\frac{1}{2}$, and 6 feet high.

Some Officers may fancy that a waterproof lean-to would not give sufficient cover. I fancy that objection is more theoretical than practical. From a good deal of personal experience in tent-life, I have no hesitation in saying that, as regards temporary shelter, anything which will keep the rain off is sufficient, except in very severe winter weather. I may state that during many fishing and shooting expeditions in Nova Scotia and New Brunswick, I have rarely had occasion to use anything for myself and Indians but a lean-to; certainly there was always an unlimited supply of firewood; and bark and fir boughs were always available to put at the ends of the lean-to to prevent the snow from drifting in.

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Pl. V.

PROPOSED WATERPROOF LEAN-TO,

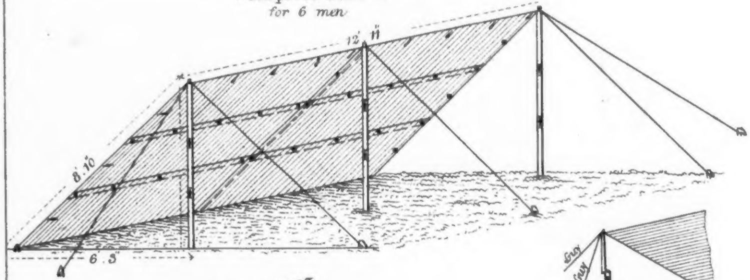
by Captain A.B. Tulloch.

Garrison instructor Halifax. N.S.

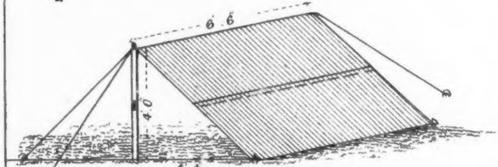
Scale 6 feet to an Inch

Weight.

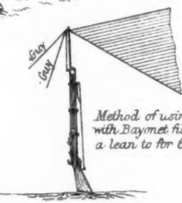
	lbs	oz
Sheet	2 .	2
Pegs and String		5
Tent Rod		10
Total weight for each man	3 .	1



Waterproof Lean to
for 6 men

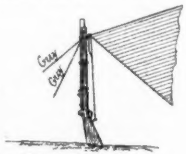


Waterproof Lean to
for 2 men

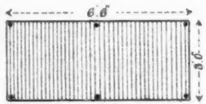


Method of using Rifle with Bayonet fixed in a lean to for 6 men

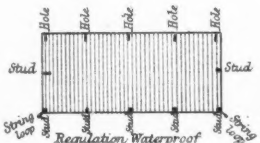
When Rod is dispensed with and Rifle used in its place, then the total weight to be carried by each man is only 2½ lbs.



Method of using Rifle in a lean to for 2 men.



Regulation Waterproof Sheet



Regulation Waterproof Sheet altered.

Ring and Swivel for use with Rifle or Rifle and Bayonet.

Detail of Tent Rod

(⅛ full size.)

Diameter ¾ of an Inch.

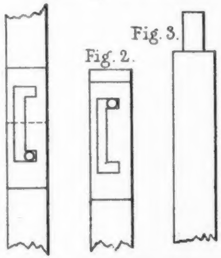


Fig. 1. Rods connected.
2. Rods apart.
3. Shows top of Rod.

J. Jobbins

The jointed rod might be dispensed with, by using a rifle in its place: all that would be required, when a height of 6 feet is necessary, would be a ring to fit on to the top of the bayonet so as to prevent the sheet slipping down over it. When a height of 4 feet only is needed, then a small double hook would answer, one end being attached to the stud-hole in the sheet, the other end hooking on to the upper swivel of the rifle. The ring might be permanently secured to the hook, so that either might be used as desired. The ends of the two guys might also be attached to the ring; by doing this, the rifle could be disengaged from the tent in a second, by simply slipping the ring off the top of the bayonet in the one case, and casting off the hook from the swivel in the other.

Many Officers object to a rifle being used at all for such a purpose, and I think that one objection, namely, possible injury to a soft iron barrel is perhaps reasonable, at least until steel barrels (Henry-Martini rifles) are introduced. By the addition of three small metal hooks and three eyes, which would not interfere with the tent arrangements, the waterproof becomes available as a cape.

I may add that a friend who has just returned from a journey across the Rocky Mountains—Fort Edmonton to British Columbia—informed me that his party had no shelter but a cotton lean-to; the time occupied in the journey was thirty days; there was much rain, and the thermometer was sometimes as low as 15° F. The health of the party did not suffer.

The question of temporary shelter resolves itself into this: Is it of so much importance that it is worth the trouble of carrying 3 lbs. 1 oz. (or $2\frac{1}{2}$ lbs. only if the rifle is used in place of the rod)? With continental nations who can draw an almost unlimited supply of men from their home depôts to repair the waste of bivouacing, it may perhaps be better policy not to burden the soldiers with the weight of a shelter tent; but in our case, with so much smaller a reserve to draw from, every man's life is of relatively greater value. I therefore venture to think that the question of carrying an increased number of waterproof sheets with the camp equipment for the purpose of obtaining cover when obliged to leave the tents behind, is one worthy of consideration.

HALIFAX, N.S.,
November 30*th*, 1872.

IMPROVED INSTRUMENTS FOR MILITARY SKETCHING.*

By A. H. HUTCHINSON, F.R.G.S., F.G.S., Major Royal Artillery, late Garrison Instructor at Aldershot.

THE increased attention which everything connected with military sketching has lately received throughout the Army generally, must be

* Exhibited at the Evening Meeting on Monday, February 3rd, 1873, Admiral George Elliot in the Chair. These instruments are made by Messrs. Elliott, Strand.

my apology for laying before the members of the Royal United Service Institution a short description of the following instruments which have been found of great assistance to the military draughtsman, not only in adding to the accuracy of his sketch, but also in materially shortening the time required for its execution.

THE IMPROVED PRISMATIC COMPASS.

Scarcely any alteration has been made in the prismatic compass since its first introduction, upwards of 100 years ago, by an instrument-maker in the Strand, and yet it possesses two serious defects—1st. Rain or moisture can penetrate the interior; 2ndly. When the glass breaks, the instrument is all but useless.

As Garrison Instructor, my attention was called to both these defects. Compasses which had lain by for a time were constantly brought in by Officers with the movement of the card interfered with, by the rusting of pin or magnet. And again, the sketcher would return from his ground with a drawing only half finished, obliged to stop, from the breaking of the glass by a fall.

To obviate these defects, I have reduced the glass on the upper surface to a minimum, allowing only just sufficient to admit the required rays of light, at the same time making the outside so secure that the entrance of moisture is all but impossible.

This improved compass has now been in constant use for upwards of twelve months, and has been favourably reported upon by both the Military Colleges at Woolwich and Sandhurst, and approved of by nearly all the garrison instructors.

It possesses the following advantages over the old pattern:—

1. There is no loose lid.
2. It is lighter and more compact.
3. Much safer and less liable to breakage, as most of the glass is replaced by metal; and, as a further improvement, the piece of glass used, is optically worked and mathematically parallel.
4. Should the glass be broken, the instrument is not rendered unserviceable.
5. No rain can penetrate to rust the interior.
6. It is provided with spare horse-hairs.
7. Does not require a leather sling-case, although one can be used if desired.
8. The steadying-spring is padded with a soft material, which acts as a buffer to the revolving card, without denting it.

9. The sight-vane can readily be raised by the knob, even with the gloves on in cold weather.
10. It is cheaper.

Directions for use.

Take the instrument out of the morocco case, which can be left at home; place the larger strap round the neck and insert the smaller one into the loop which secures the prism, allowing the compass to hang in front of the body, with the sight-vane outwards. A slit in the smaller strap will fasten on to a button of the coat, should further stability be desired.

To take a bearing, raise the sight-vane and erect the prism; afterwards allowing the instrument to fall upon the breast till required for further use. If a fresh horse-hair be required, cut it off the bunch at both ends and draw it out. To get at the card, merely raise the top-half of the compass.

THE NEW SURVEYING ANEROID.

All military draughtsmen agree in the necessity of showing upon the drawing, the relative heights of the different hills, or other important points.

Hitherto a clinometer of some kind or other has been almost the only instrument available for the use of the military sketcher. The process is a tedious one, the time occupied considerable, and should the thread, so to speak, once be lost, it can only be picked up again by returning (perhaps some considerable distance) to any known level.

The new surveying aneroid is intended to take the place of the clinometer as soon as the student has learnt to read by eye the various slopes he is likely to meet with.

This small instrument, carried in the pocket like a watch, can be referred to at any moment.

No time need be lost in ascertaining the different slopes of the ground to be sketched. One observation at the base of a hill and another at the summit, will at once give the number of contours to be inserted, their distance apart being determined by the eye.

It may be also useful in ascertaining the level of some height, which can only be occupied by the observer for less than a minute, and which may be totally unconnected with any part of his previous sketch.

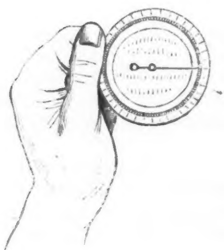
It can be used for any elevation up to an altitude of 3,000 feet above the level of the sea.

By its help, contours of 25 feet and upwards can easily be determined, either by running sections or otherwise.

Experiments have also been carried out which prove that, comparing it with the present tedious process, at least three times as much ground can be sketched in the same time, and with far greater accuracy.

It is carefully compensated for temperature, and forms a reliable weather-glass of the best construction.

Directions for use.



1. Always hold the instrument by the handle in the left hand, the eye level with the needle.

2. When the observer ascends, the point of the needle rises; when he descends, the needle falls; and the difference of level is read off at once on the moveable arc, each of the smallest divisions representing 25 feet.

3. It is desirable to put the instrument, without its case, in the pocket a few minutes before it is used. To set it, place the zero on the moveable arc opposite the point of the needle.

4. Should the weather be unsettled, observations must be taken frequently and for small altitudes, moving the zero-point each time. In fine weather, the arc may remain fixed throughout the day.

5. Tap the instrument lightly with the finger on the centre of the back.

Major HUTCHINSON: I should wish to say a few more words about the new aneroid, because we have introduced in this instrument, something which will be of very great service, especially to army sketchers. The compass has passed through two years' ordeal, but with the aneroid we have only had six months' experience. It has been put into the hands of sketchers at Aldershot who have used it for a month or six weeks, being pitted against Officers measuring ground according to the old plan. So great has been the advantage of this instrument, that several of those who were employed in sketching with the others, have given them up, saying that it was perfectly impossible to go on with them any longer. I have adopted the principle that for all purposes of reading heights with an aneroid it must be held in one direction. It is no use taking the aneroid out of your pocket, and tapping it, and looking at it when it is flat, unless it is one of the most expensive ones. The principle of this new aneroid is this, that you can make your contours with the aneroid only. You can find the height of any hill, however small, with it, and you can go on mapping out your country with this little instrument, and you can do so with accuracy. Suppose there is a hill there, and we have only time to rush up it, and it is of importance that we should go up there with regard to placing guns on another hill. Well, a man gallops up and down again at once and brings the information in a moment.

Captain COLOMB, R.N.: How low will the aneroid register?

Major HUTCHINSON: One contour, viz., 25 feet, but you can take half that if you wish.

Captain SELWYN, R.N.: May I ask if there is any larger scale of aneroid on that system which would register smaller variations of height?

Major HUTCHINSON: A larger aneroid than this would not suit us in the Army.

Captain SELWYN: There has been one brought before the public, of 3 inches diameter, which professes to register 1 foot. I mention this because I have been using them in mines in America, and if you could give us one which would register even 2 or 3 feet, they would be of the greatest value to the miner. My own aneroid,

(one of Elliott's) will register a difference of 10 feet at moderate elevations, but I could not always rely upon it when I got up to the 9,000 feet elevation above the sea common in the Rocky Mountains.

The CHAIRMAN: We are much obliged to Major Hutchinson for coming here and showing us these instruments.

ON BREMNER'S STEAM-STEERING-SCREW.*

By Captain GEORGE BREMNER.

IN addressing a company of gentlemen who are professionally and scientifically conversant with steam navigation, it is not necessary to enlarge on the importance of an invention such as that which I have the honour to bring before your notice this evening.

My invention, which I call a steam-steering-screw, has for its object to effect the turning, manœuvring, and revolving of a ship, and it claims to do that without the necessity of headway.

It will be readily conceded that the greatly increased length and dimensions of modern-built ships, especially those belonging to Her Majesty's Navy, require a mechanism more ready and more efficacious than the old-fashioned rudder to perform the evolutions required of them. I trust to be able to demonstrate, by the aid of the working model, that my invention would revolve a ship completely, without, as hitherto, the necessity of steerage way; I believe no mechanical appliance has hitherto been able to accomplish this.

It has justly been remarked that year by year, the sea, especially those parts of it which wash the shores of Europe, is becoming more crowded. The painful result is seen in the increase of accidents, chiefly arising from collisions. Even at the present moment the country is mourning for a fearful catastrophe which resulted from an accident of this kind. Careful navigation may do much to avoid these fatalities; well-considered sailing rules and directions may do much to lessen them; but even after both are accomplished, accidents to a certain extent will remain unavoidable. It is necessary therefore that every device or invention that will facilitate the movement of vessels under these circumstances should be applied, more especially to those steam ships whose trade leads them constantly into channels much frequented and crowded, and therefore especially liable to the diasters of collision or stranding.

The invention I have the honour to submit to you this evening will, in my opinion, if properly applied, be some remedy for this kind of disaster; for even when collision is imminent, the vessel provided with it may be turned, and the threatened collision altogether averted. I have confidence in asserting that its general adoption would tend

* Read at the Evening Meeting on Monday, February 3rd, Admiral George Elliot in the Chair.

to avoid the majority of those distressing accidents which are constantly occurring, and thereby save life and property from destruction to an extent impossible to estimate.

There are other valuable advantages connected with the steering screw, which I will indicate as briefly as possible. Among these is the power it gives of keeping a ship in position when hove-to or compelled to go at a very slow speed in heavy weather, and thus preventing her falling into the trough of the sea and eventually foundering, as is too frequently the case.

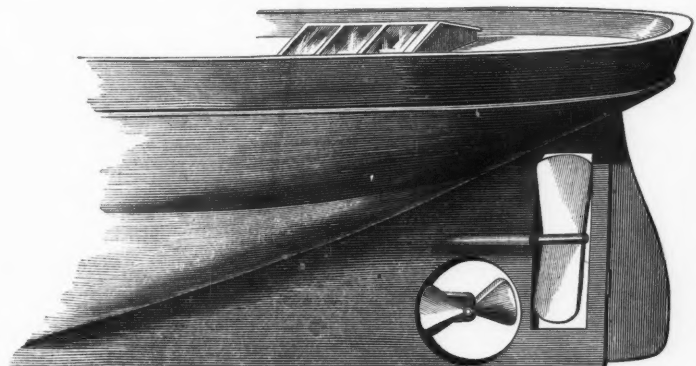
But especially when applied to ships in narrow waters would this invention be valuable, and above all to vessels sailing through the Suez Canal. The traffic through the canal, now the high road to India, is rapidly increasing. Owing to the tortuous nature of the channel, it has been found necessary to maintain a number of steam-tug boats, which are employed in the sole occupation of turning the heads of vessels, this expedient being necessitated by the inability of the ships themselves to turn in the confined waterway open to them. This of course would be obviated were this invention generally adopted; consequently a vast saving would be effected both in time and in money. Moreover, should any accident happen to the rudder of a vessel through grounding, or from any other cause, this steering-screw would constitute a second rudder, and in case of need, one by which the ship could be as readily steered as by the old one.

It is, however, in its application to vessels of war that I would more particularly draw your attention. The exigencies of modern warfare require that a ship should be able to bring her guns to bear on her opponent with the maximum effect, and at the same time with the minimum of danger to herself. Hence the adoption of the turret system. The present invention is not, however, at all antagonistic to the turret. On the contrary, it is a development of it, for instead of only a section of the ship being turned round, it would enable her Commander to revolve the ship herself. Further, I believe I am not overstating the case when I assert that the ship can be as readily turned round as the turret; if I prove such can be done, I think all will agree with me that a vessel possessing this power if she be well handled, will be a match for any two of her size without it. It must be patent to all that every means that facilitates the movements or evolutions of a ship, increases her power of both offensive and defensive warfare. There are times when vessels unfortunately find themselves so near stranding that all chance of their being saved is gone, unless they can be turned without being compelled to gain steerage way. For this one purpose only, I take it that this invention is invaluable, as we have instances of this kind almost daily coming before us. This invention is applicable to any existing ship, for iron-ship building has enabled us to do many things with ships that previously would have been quite impossible or altogether unsafe.

Prior to the introduction of the turret system, a vast amount of money was spent in the building of broadside vessels. If these vessels could be rendered revolvable, as are the turrets, it is self-evident that their belligerent power and formidableness would be infinitely increased,

and the expenditure of an enormous amount of money in building new vessels would be altogether avoided; a very material consideration in these days of retrenchment, especially when we remember that many of these vessels cannot be surpassed either in their models or their fighting qualities for sea as well as coast service. But as we must still go on building and improving, I have formed an opinion which I may be permitted to express, that a class of small ships for end-on fire, having deflective armour and fitted with one or two heavy guns so that they can approach any fort or other opposing power, and be able to deliver a destructive fire with immunity to themselves, would be a serviceable class of ships and a most important adjunct to our maritime forces. In order to maintain the position of "end-on fire," I know of no other means than the application of the steering-screw. Every practical man must be aware of the difficulty of keeping and maintaining a ship in that position.

I will now proceed to describe as briefly as possible the invention itself. One of its leading characteristics is its extreme simplicity, and it may be said to be founded on a principle already acknowledged by all conversant with naval matters.



I form a circular aperture near the heel of the ship, in what is technically termed the dead-wood, below the line of the ordinary screw-propeller shaft, and as close to the keel as possible. A water-tight trunk is fitted, either horizontally or vertically, in the vessel, extending sufficiently far into the circular aperture above alluded to, and made of sufficient strength to carry the weight and pressure of the screws when in full operation. Two chain-driving wheels are placed in this trunk, one at each extremity, having an endless chain round them and mounted on shafts, the arms of which extend outside the side or walls of the trunk, and are packed water-tight in the usual way. To the arms of the after-shaft the steering-screws are attached, one on each side, and

to the arms of the inner-shaft the motive power required to drive them, which can be led on deck to a donkey-engine or steam-winch, or worked by a small engine below. Experience has taught me that it is necessary for the actual successful working of these screws that they must be placed as low as possible in the ship, where the water may be said to be the densest and the least disturbed by the motion of the vessel, and where a perfect bite upon the water can be at all times obtained by the screws.

My patent embraces many mechanical ways, such as arms and cranks for working these screws; but for the purposes of my own experiments on these models I have preferred to use the endless chain, as I find I get immediate action with an equal distribution of strain on all parts; and as it might be found necessary at times to put on full power, without being able to commence the action slowly, my opinion is that the system of the endless chain will be found preferable.

The CHAIRMAN: I am sure we must thank Captain Bremner for the trouble he has taken in bringing this invention to the notice of the members, and for exhibiting to us such beautiful working models as those now before us.